FRED Reports

Lower Yukon River
Hatchery Site Investigation
Volume One
BY
Robert McLean
and
J.A. Raymond
Number 12

ALASKA
DEPARTMENT OF FISH AND GAME

Alaska Department of Fish & Game
Division of Fisheries Rehabilitation,
Enhancement and Development

Lower Yukon River
Hatchery Site Investigation
Volume One

By
Robert McLean
and
J.A. Raymond

Number 12

Alaska Department of Fish and Game
Division of Fisheries Rehabilitation,
Enhancement & Development

Don W. Collinsworth
Commissioner

Stanley A. Moberly
Director

P.O. Box 3-2000
Juneau, Alaska 99802

August 1983

TABLE OF CONTENTS

LIST OF FIGURES

LIST OF TABLES

APPENDIX TABLES

ABSTRACT

The Lower Yukon River drainage (LYR) was searched for potential Pacific salmon (Oncorhynchus spp.) hatchery sites. Data were collected on 215 sites, 101 of which were visited. Fifteen locations in the LYR were identified as potential sites for small-scale (1-5 million egg capacity) fall chum salmon hatcheries. These sites include the villages of Ruby, Holy Cross, Russian Mission, Marshall and St. Mary's. Because of limited water supplies or access limitations, no sites were found that would accommodate a production-scale (>10 million egg capacity) hatchery with a conventional (non-recirculating) water supply. Water supplies at several villages were so limited that even a small-scale hatchery would not be possible without recirculation. Recirculation technology needs further development before it can be used in the LYR. Greater water supplies might be obtained in some villages through wells that reach below the permafrost layer. Although fall chum salmon (O. keta) were considered the species best suited for enhancement in the LYR, chinook salmon (O. tshawytscha) appeared to have some potential.

Opinions of fishermen in the LYR concerning salmon enhancement were also obtained. Although many fishermen expressed an interest in salmon enhancement when they were interviewed, there did not appear to be a spontaneous demand for it. This was primarily due to the fishermen's unfamiliarity with salmon enhancement concepts and their questions about the impact of hatchery fish on wild fish and on a subsistence lifestyle. There is a strong need for education of Yukon River fishermen on salmon biology and salmon enhancement techniques. A small-scale educational hatchery placed in one or more villages would do much to satisfy this need. It is likely that there will be a stronger demand for hatchery production in the future as Yukon River fishermen become more familiar with hatchery methods and as demands on wild salmon increase. If a production-scale hatchery is to be built, most LYR fishermen wanted it to be located upriver from their village.

KEY WORDS: fish culture, Oncorhynchus spp., salmon, whitefish, Yukon River, Koyukuk River, Haul Road, hatchery site investigations, water sources, springs, recirculation.

INTRODUCTION

The Division of Fisheries Rehabilitation, Enhancement and Development (FRED) of the Alaska Department of Fish & Game was asked by the 1980 Alaska Legislature to conduct a hatchery site investigation in the Lower Yukon River region (LYR). For this study we defined the LYR as the Yukon River drainage below the village of Tanana (Figures. 1 and 2). This area includes the Koyukuk River drainage.

Little hatchery site investigation work has been conducted in the LYR. One study was confined to Lower Yukon villages and resulted in the construction of a nonprofit hatchery in Mountain Village in 1978. However, problems with water availability and financing have kept it from operating. A survey of water temperatures and flows in the Upper Koyukuk drainage, which was conducted as part of a hatchery site investigation, revealed abundant water in winter but low water temperatures (Raymond 1979). A survey was conducted among commercial and subsistence fishermen along the entire Yukon River in Alaska to determine which species of fish they would like to see produced by a hatchery. Respondents living in the LYR indicated a fairly even preference for fall chum, summer chum, chinook and coho (O. kisutch) salmon (Raymond 1977). Pope (1980) surveyed the historical relationships of the commercial and subsistence salmon fisheries in the Yukon River area in relation to the Limited Entry Program but did not address the issue of salmon enhancement.

We attempted to answer two questions in this study: (1) What water sources are in the LYR that are both reasonably accessible and of suitable quality for salmon culture, and (2) how do fishermen in the LYR feel about salmon enhancement and rehabilitation in their region. Although many considerations are involved in hatchery site selection (Baker 1977), we put most of our effort into identifying water sources because we felt that this was the factor that was most responsible for limiting hatchery development in the LYR.

Because we expected difficulty in finding suitable water sources, a separate study was conducted to evaluate the feasibility of a recirculating hatchery that could be placed in villages with limited water supplies (Raymond 1981).

This report appears in two volumes. Volume 1 contains the main results of the survey. Volume 2 contains water quality analyses, well logs and aquifer tests for many of the sites investigated.

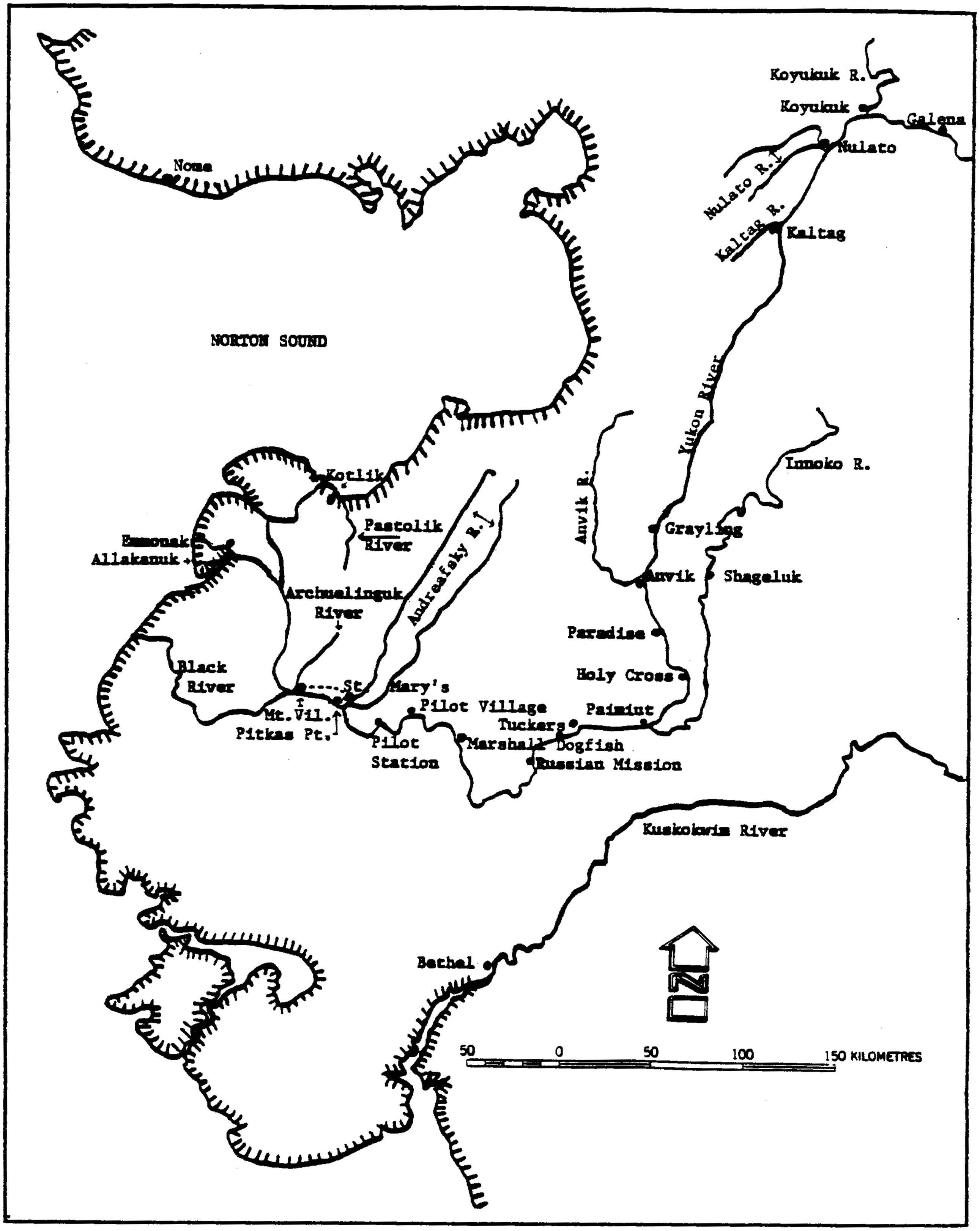


Figure 1. Map of the Lower Yukon River from the Yukon Delta to Galena.

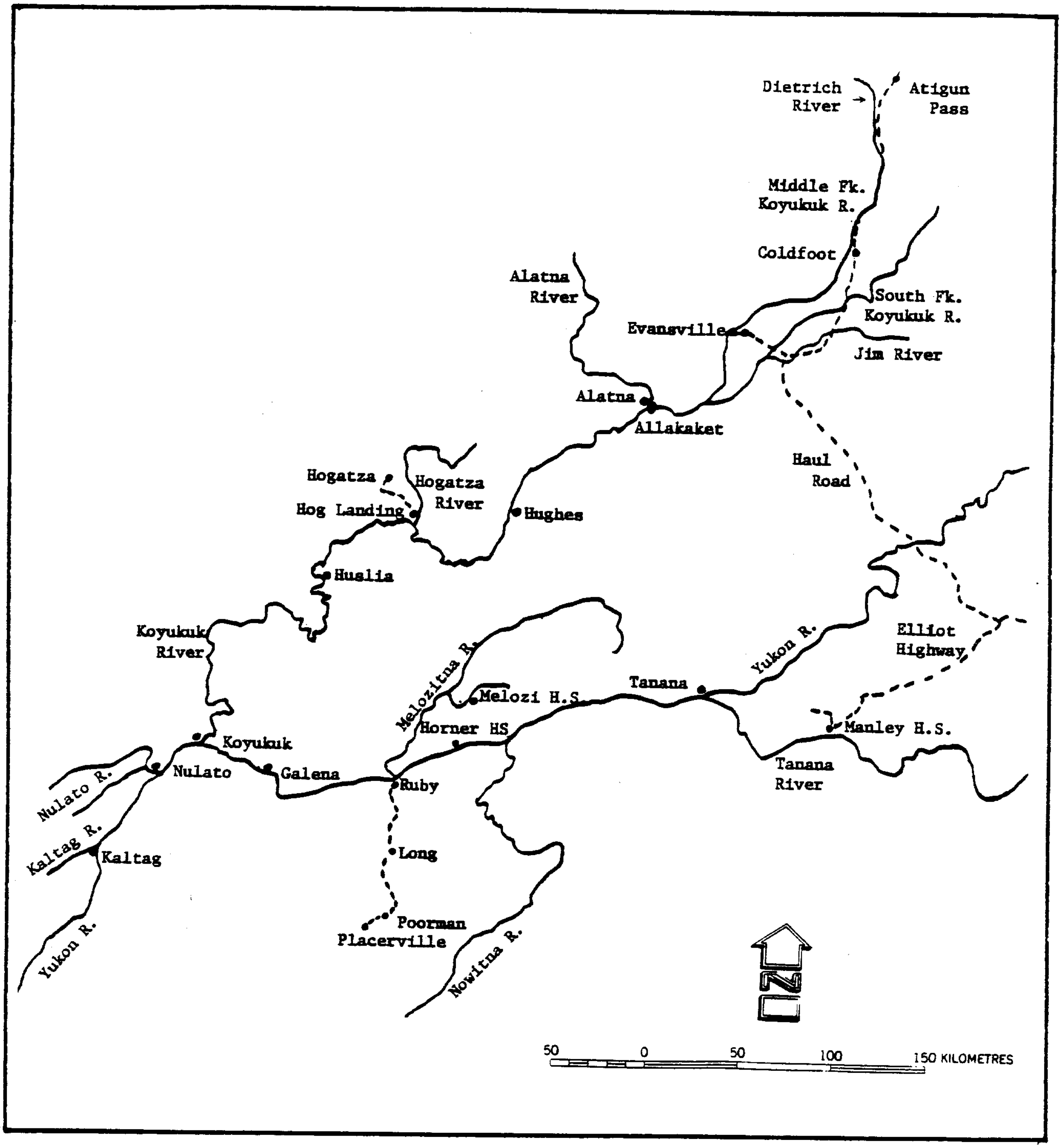


Figure 2. Map of the Lower Yukon River from Kaltag to Tanana, and the Koyukuk River.

MATERIALS AND METHODS

Ten field surveys were conducted (Table 1). Data were collected through both field investigations and interviews. Meetings were also arranged to discuss salmon enhancement in some villages (Table 2). Because of the high costs associated with building and operating a remote facility, we confined our study to sites in or near villages or roads that are open year-round.

Water temperatures were measured with a mercury thermometer with 0.1°C divisions. Small water flows were measured with a collapsible water container and stop watch. Larger water flows were measured by estimating average width, depth and water velocity. Water samples were collected in 1 liter polyethylene bottles containing 10 ml nitric acid and analyzed by Northern Testing Laboratories.

RESULTS

Existing commercial and subsistence fisheries

The commercial and subsistence salmon catches in the LYR are given in Table 3. The average total salmon catch has been about 1.25 million salmon per year, which is about 2% of the total catch for the state. However, both the commercial and subsistence catches vary considerably from year to year. Most of the salmon are caught near the mouth of the Yukon River where a large commercial fishery is located. About 19% of the total catch is used for subsistence. However, the proportion of the catch that is used for subsistence can reach 50% or more in upriver areas. In the Koyukuk River, the subsistence fishery is the only fishery.

Hatchery Site Observations

Two-hundred-fifteen sites were investigated for hatchery development along the Haul Road, in the Lower Koyukuk River, and along the Yukon River below Tanana. Water flows and temperatures for these sites are given in Appendix Tables 1, 2 and 3, respectively. (Water quality analyses and well tests for many of these sites are given in Volume 2). Additional comments on 31 of the more important locations are given below. Fifteen of these sites appear to have some potential for hatchery development and are marked with an asterisk.

In the following, site numbers refer to the order in which sites appear in Appendix Tables 1, 2 and 3. Water quality at various locations is usually given relative to state water quality criteria for fish culture which are given in Appendix Table 4.

Table 1. Field surveys conducted for the Lower Yukon hatchery site investigation.

Date	Locations
9/26/80 to 10/2/80	Tanana, Ruby, Horner Hot Springs, Galena, Nulato, Kaltag
10/2/80 to 10/4/80	Jim River, Middle Fork Koyukuk River, Dietrick River
10/14/80 to 10/18/80	Bethel, Russian Mission, Marshall, Holy Cross, Anvik, Grayling
11/9/80 to 11/13/80	Bethel, St. Mary's, Mountain Village
2/4/81 to 2/7/81	Bettles, Allakaket, Alatna
2/17/81 to 2/19/81	Horner Hot Springs, Ruby
2/23/81 to 2/25/81	Galena, Huslia
3/8/81 to 3/12/81	Nome, Kotlik, Holy Cross, Marshall, Mountain Village
4/7/81 to 4/9/81	St Mary's, Holy Cross, Russian Mission, Marshall, Mountain Village, Bethel
4/13/81 to 4/15/81	Jim River, Middle Fork Koyukuk River, Dietrich River
7/26/81 to 7/28/81	Ruby, Long

Table 2. Meetings arranged to discuss salmon enhancement in the Lower Yukon River region.

Village	Date	No. Participants
Kaltag	9/30/80	14
Nulato	10/1/80	12
Allakaket	2/5/80	15

Table 3. Commercial and subsistence salmon catches in the Lower Yukon River drainage, 1971-1980. The fishing districts given below are approximately the mouth of the Yukon River to Mountain Village (Y-1), Mountain Village to Marshall (Y-2), Marshall to Anvik (Y-3), Anvik to Tanana (Y-4), Tanana vicinity (Y-5-1) and the Koyukuk River (Koy.).

		Thousands of salmon					
		chum		chinook		coho	
Dist.	Fishery	Ave.	Range	Ave.	Range	Ave.	Range
Y-1	Comm.	443	(251-642)	68	(45-88)	15	(2.2-34.9)
	Subs.	27	(17-35)	2.3	(0.5-5.2)		
Y-2	Comm.	165	(6-394)	24	(11-51)	1.9	(0-5.8)
	Subs.	32	(24-41)	3.7	(1.4-4.9)		
Y-3	Comm.	21	(0-69)	4.0	(2.9-5.2)	0.6	(0.5-0.8)[2]
	Subs.	6	(2.2-9.4)	3.8	(2.6-5.1)		
Y-4[1]	Comm.	216	(37-376)[4]	0.9	(0.4-2.0)[4]	0.1	(0-0.2)[3]
	Subs.	106	(32-207)	5.4	(3.8-10)		
Y-5-1	Comm.	57	(12-112)[4]	3.2	(2.3-4.9)[4]		
	Subs.	23	(11-39)	1.5	(0.1-5.7)		
Koy.	Subs.	23	(4.7-43)	0.4	(0.1-0.7)		
Total	Comm.	902		100		18	
	Subs.	217		17			

1. Does not include Koyukuk River
2. Data available for 1977 and 1978 only
3. Data available for 1978 and 1979 only
4. Data available for 1974-1980 only

Water flows are given in liters per minute (lpm). One gallon per minute equals 3.78 lpm and one cubic foot per second equals 1699 lpm.

*Dietrich River (Site 1; Fig. 3). This river has a winter flow of 5,ØØØ lpm. The winter water temperature is Ø°C but many sections remain open, apparently because of the high gradient (19 m per km). The gradient and flow may be sufficient to power a small hydroelectric unit. The Dietrich River is accessible year-round by the Haul Road.

*Spring near Dietrich River (Site 4; Fig. 4). This spring flows from the bottom of a hillside 5Ø m east of the Haul Road at pipeline mile post 19Ø. On 3 October 198Ø it flowed 3,1ØØ lpm at 8.5°C and on 14 April 1981 it flowed 2ØØ lpm at 8.1°C. The water was relatively hard (39Ø ppm $CaCO_3$) and had a low pH (6.43) and a low dissolved oxygen concentration (3.5 ppm).

*Jim River Bridge #3 (Site 23). The Haul Road crosses the Jim River at this site 5 km north of Prospect Camp. About 1 km downstream from the bridge the river was flowing approximately 89,ØØØ lpm at Ø°C on 14 April 1981. A water intake is located in the middle of the River at the bridge and is apparently used throughout the winter to fill water trucks. Chum salmon are reported to spawn in the Jim River below Prospect Camp.

Allakaket (Sites 49-53). Ground water is available in only small quantities (3Ø to 5Ø lpm), and its iron (Ø.19 to Ø.76 ppm), chloride (3.Ø to 7.Ø ppm), magnesium (9.7 to 43 ppm) and maganese (Ø.Ø6 to Ø.47 ppm) concentrations, and pH (7.9 to 8.4) exceed recommended maximum values. Although the Koyukuk River at Allakaket appears to have good water quality, it occasionally becomes turbid in the spring and summer. The site of a reported spring near the Alatna Bluff was visited on 5 February 1981 but no flow was observed.

*Clear and Caribou Creeks (Sites 54-55). Both creeks are located in the Zane Hills near Hog Landing on the Koyukuk River approximately 66 km by air from Hughes. The creeks are reported to be spring fed and to have ice-free areas through the winter. Caribou Creek has numerous small spring seeps reported in the lower two-thirds of the creek below the road crossing and both creeks appear to carry more water than would be expected from the size of their watersheds (Fred Anderson, personal communication). Stream gradients, determined from a topological map, are approximately 11 m per km. On 18 July 198Ø, 12,4ØØ and 7,4ØØ chum salmon were observed in Clear and Caribou Creeks, respectively (ADF&G, 198Ø). All spawning chum salmon were observed in the areas that were reported to be spring fed. The creeks appeared to be about 7 m wide (Fred Andersen, personal communication).

The creeks are accessible during the summer by the Hogatza road, which starts at Hog Landing on the Koyukuk River. Barge service is available to Hog Landing. Alaska Gold Company has a 975-m by

21-m gravel airstrip at Bear Creek on the Hogatza Road that may be used with permission.

Hughes (Sites 58-61). The village well produces only 57 lpm and the iron (0.7 ppm), manganese (0.12 to 1.4 ppm), and nitrate (1.5 to 2.1 ppm) concentrations exceed the recommended maximum values. Three geothermal springs are reported within 20 km of Hughes but we were unable to locate any additional data on them.

Huslia (Sites 68-92). The village well produces only 90 lpm, and the iron (7.5 ppm), manganese (0.35 ppm), and arsenic (0.03 ppm) concentrations exceed the recommended maximum values. No springs are known near Huslia. In addition to the public well, Huslia has several private wells.

Koyukuk (Site 93). The village well produces only 23 lpm and the iron (0.5 ppm), lead (0.03 ppm), and manganese (0.4 ppm) concentrations exceed the recommended maximum values. No springs are known near Koyukuk.

Tanana (Sites 103-113). Groundwater production from the village well is variable (4-190 lpm), and its iron (0.78 to 7.6 ppm), manganese (0.16 to 0.97 ppm), magnesium (7.3 to 50 ppm), and chloride (15.5 to 29 ppm) concentrations exceed the maximum recommended values. Tanana has several private wells in addition to the public well. Although water quality in the Tozitna River appears good, a site on this river would require about 6 km of new road and a means for heating the water. A submerged spring is reported in the Tozitna River 1.2 km below its confluence with Crooked Creek which is approximately 40 km by air north of Tanana.

*Horner Hot Springs (HHS) and HHS Creek (Sites 115-116; Figs. 5 and 6). These sites are located approximately 1.2 km north of the Yukon River, approximately 37 km upriver from Ruby. The main spring is located on a granitic cliff 12 m above the west bank of HHS Creek (110 m above of the Yukon River). The main spring flows 170 lpm at 48°C. HHS Creek flowed 1,100 lpm at 0.8°C on 18 February 1981. The water quality in HHS Creek is unknown.

Several smaller springs are located on HHS Creek between 160 and 320 m upstream from the main spring. Six are on the west bank and one is on the east bank. These springs are between 0.6 and 6.1 m above the creek, range in temperature between 30 and 49°C, and have a combined flow of 75 lpm.

*Ruby Public Health Service Well (Site 120). The village well produces only 81 lpm, but only the magnesium concentration (22 ppm) exceeds the recommended maximum values. Ruby has a 790 m by 15 m airstrip and scheduled air service from Galena and Fairbanks. Yutana Barge Lines, based out of Nenana, provides river freight service.

*Midnight Creek Springs (Site 128). These springs are located at the headwaters of Midnight Creek on the east side of the Ruby-Poorman Road approximately 64 km south of Ruby. Midnight Creek is reported to flow year round and to be used for drinking water. The creek flowed 11,000 lpm at 2.1°C on 27 July 1981 at the road crossing. The headwater springs flowed a total of 710 lpm at 1.2°C on the same date. Neither the creek nor the springs have been analyzed for water quality. However, springs at sites 123 and 124 which are located in the same upland geologic structure closer to Ruby, appear (from PHS records) to have good water quality. Midnight Creek Springs are accessible by a good road during the summer months. The closest airstrip is located at Long, approximately 10 km north of the springs.

*Melozi Hot Spring and Melozi Hot Spring Creek (Sites 130-131). Melozi Hot Spring is approximately 48 km northeast of Ruby by air and has a privately owned, 366-m by 8-m dirt airstrip. The airstrip was in poor condition in April 1981. The mouth of Melozi Hot Spring Creek which is approximately 16 km below the hot spring is accessible by boat. The hot spring flows 492 lpm at 56°C. On 29 July 1980 6,300 chum salmon and 11 king salmon were observed spawning in Melozi Hot Spring Creek between its mouth and the hot spring.

Galena (Sites 141-143). The city's two wells each produce only 95 and 98 lpm, and the iron (32 to 34 ppm) and manganese (0.05 to 1.5 ppm) concentrations exceed recommended maximum values. No springs are known near Galena.

Nulato (Sites 144-148). The village well produces only 38 lpm and the iron (0.15 to 0.6 ppm), manganese (0.37 ppm) and magnesium (38 ppm) concentrations exceed recommended maximum values. The Nulato River has a large chum salmon run and thus probably has good water quality. The Nulato River is accessible by road. No springs are known near Nulato.

Kaltag (Sites 149-153). The village well produces only 28 lpm, and the iron (22 ppm) and manganese (0.4 to 0.85 ppm) concentrations exceed recommended values. Two springs are located on the Kaltag River. One had an estimated flow of 160 to 380 lpm. A chemical analysis of the other revealed no metal concentrations exceeding recommended maximum values. However, 4 km of new road would be required to provide access to this spring. Although water quality in the Kaltag River appears to meet state aquaculture water quality standards, a site on this river would require about 1 km of new road.

Grayling (Sites 154-156). The village well produces only 110 lpm and the iron concentration (0.2 ppm) exceeds the recommended maximum value. Hydrogen sulfide is present in some private wells. Grayling Creek is accessible by road and flowed 509,800 lpm on 17 October 1980. However, its iron concentration (0.56 ppm) exceeds the recommended maximum values. No springs are known near Grayling.

Anvik (Sites 157-165). The village well produces only 4 to 110 lpm, and the iron (0.1 to 19 ppm), manganese (0.1 ppm), magnesium (16 to 21 ppm), and nitrate (2.1 ppm) concentrations exceed recommended maximum values. Iron bacteria and hydrogen sulfide are also present. Water quality in the Anvik River appears good because it has a large wild chum salmon population. However, a site on the Anvik River would require about 4 km of new road and a means for heating the water. No springs are known near Anvik.

*Holy Cross Spring (Site 167; Figs. 7 and 8). Located in a small ravine at the end of a road 1.6 km south of Holy Cross, this spring was formerly used for the village water supply. On 16 October 1980 the spring flowed 430 lpm at 2.2°C and on 8 April 1981 it flowed 71 lpm at 1.6°C. The water quality of this spring appears to meet state aquaculture water quality standards except that the iron concentration (0.116 ppm) slightly exceeds the recommended maximum value.

*Holy Cross Public Health Service Well (Site 170). This well produces only 90 lpm but the water temperature is relatively warm (2.4 to 2.9 $^{\circ}$C). Total iron concentration (0 to 0.37 ppm) has fluctuated and may occassionally exceed the recommended maximum value. Holy Cross has a 1036-m by 15-m gravel airstrip, scheduled air service and barge service.

*Unnamed Creek near Dogfish Village (Site 172; Fig. 9). This creek flows into Tuckers Slough 1.4 km above its confluence with the Yukon River near Dogfish Village. Observed from the air on 8 April 1981, the creek appeared 90% open, about 3 m wide and at least 30 cm deep. Small current ripples were observed. The estimated minimum flow at its mouth was 1,600 lpm. The creek is accessible by boat from Russian Mission, located 30 km downriver.

*Russian Mission Public Health Service Well (Site 176). Iron (0.3 ppm), manganese (0.02 ppm), and nitrate (1.6 to 15 ppm) concentrations of well water at this site exceed the recommended maximum values. Water temperature ranged from 6.1°C on 15 October 1980 to 3.6°C on 8 April 1981. The water temperature at another well, now abandoned, was 3.3°C on 2 June 1968. The well delivered 227 lpm on 15 October 1980 and 109 lpm on 8 April 1981. Public Health Service soil test analysis suggests that the Russian Mission aquifer is capable of supplying larger quantities of water. Russian Mission has scheduled air service and a 457 m by 18 m gravel and dirt airstrip. Air service is frequently interrupted by winds in fall and winter and by flooding in spring. Yutana Barge Lines provides local service.

*Marshall Airport Spring (Site 185; Figs. 10 and 11). This spring is 90 m west of the Marshall airport and 15 m south of the airport access road. Its elevation is 15 m above the Yukon River high water mark. Water flow was 189, 28.2, and 14.4 lpm on 16 October 1980, 11 March 1981 and 8 April 1981, respectively. Water quality of this spring appears to meet recommended values, except that the manganese (0.012 ppm) and nickel (0.022 ppm) concentrations slightly exceed recommended maximum values. Temperature ranged from 1.8 to 1.1°C during the above sampling period.

Marshall has a 427-m by 23-m gravel airstrip and scheduled air service from Bethel and St. Mary's. The airstrip is subject to severe turbulence. A new 914-m airstrip was scheduled for construction in the Summer of 1981. Barge Service is provided by Black Barge Lines at St. Michael's and Yutana Barge Lines at Nenana.

Pilot Station (Sites 189-190). Ground water availability is low (95 to 110 lpm per well), and its iron (0.14 ppm) and mercury (0.0026 ppm) concentrations slightly exceed recommended maximum values. No springs are known near Pilot Station.

Pitkas Point (Site 191). Ground water availability is unknown, but iron (0.39 ppm) and manganese (2.7 ppm) concentrations exceed recommended maximum values. No springs are known near Pitkas Point.

*St. Mary's Mission Well (Site 193). This 37-m deep well is located on a hillside 30 m from St. Mary's Mission School. The well is currently unused but previously produced 6 to 8 lpm. Water quality records are not available but the water's taste was reported as excellent.

St Mary's has scheduled jet air service from Anchorage. Barge Service is provided by Black Barge Lines at St. Michael's.

*Alstrom Slough Creek (Site 194; Fig. 12). This creek underpasses the St. Mary's airport road. A Public Health Service infiltration gallery at this site supplies 189,000 liters of water per day (130 lpm) to the village throughout the year. The creek flowed 14,000 lpm at 0°C on 10 November 1980. On 9 April 1981 0°C water 6 cm deep and about 50 cm wide was found below 46 cm of ice. A water flow of 290 lpm was estimated. Iron (0.3 ppm) and chloride (6 ppm) concentrations exceed recommended maximum values.

Mountain Village (Sites 210-217). Ground water availability is variable (19 to 110 lpm per well), and its iron (0.2 to 5.0 ppm), manganese (0.03 to 0.87 ppm), and lead (0.16 ppm) concentrations exceed recommended maximum values. A spring is located 200 m west of the village. We estimated that the flow was 28 lpm on 11 November 1980. Local residents reported that a second spring was located near the unfinished Lower Yukon/Kuskokwim Aquaculture Association Hatchery. We looked for this spring on 8 April 1980 but failed to find it.

Alakanuk (Site 218-219). Fresh ground water is unavailable. Three drilling attempts by the Bureau of Indian Affairs and the Public Health Service all produced salt water. No springs are known near Alakanuk.

Figure 3. Upstream view of the Dietrich River (Site 1) at P/L MP 180.75, 14 April 1981.

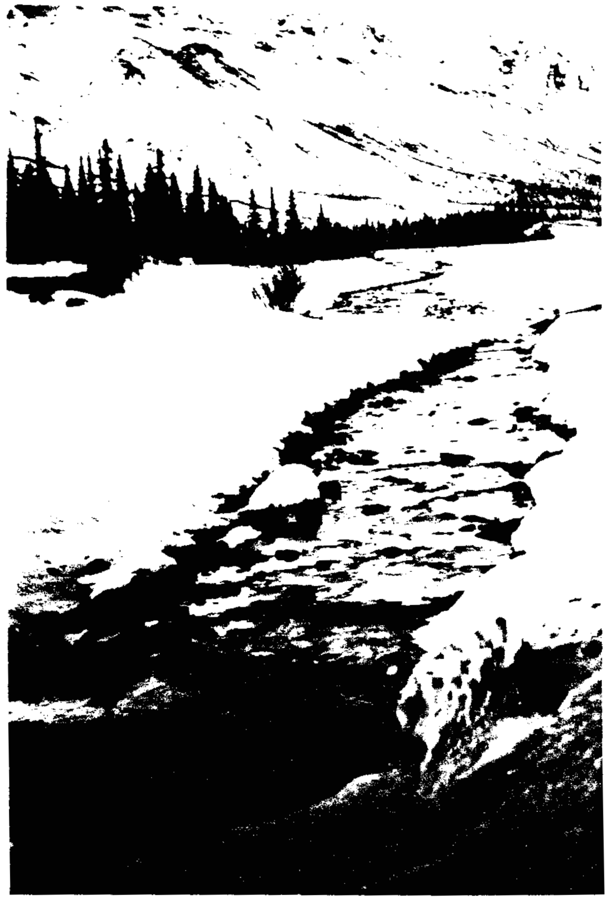


Figure 4. Downstream view of the spring along the Dietrich River at P/L MP 190, 14 April 1981.

Figure 5. View of the principal spring at Horner Hot Springs (Site 115), 29 September 1980.

Figure 6. Upstream view of Horner Hot Springs Creek (Site 116) and the outfall of the principal hot spring (Site 115), 29 September 1980.

Figure 7. View of Holy Cross Spring (Site 167), 16 October 1980.

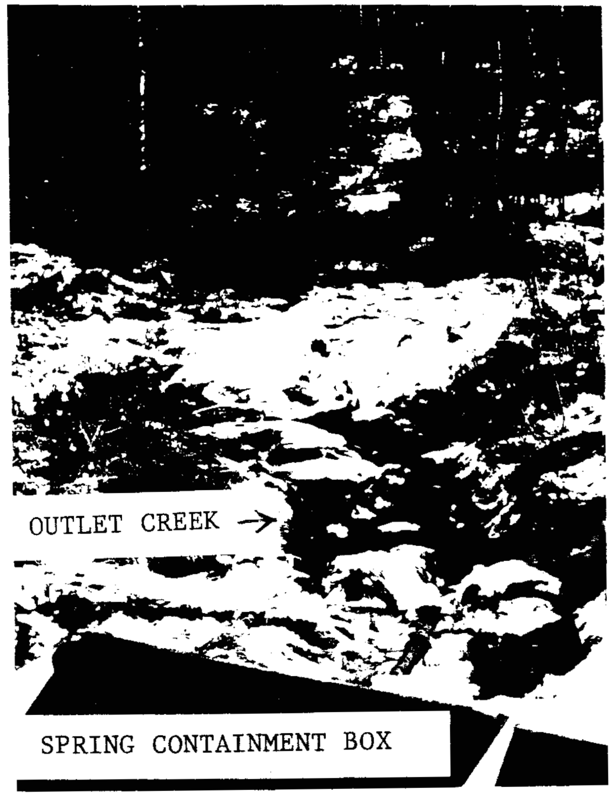


Figure 8. Aerial view of Holy Cross Spring (Site 167), 11 March 1981.

Figure 9. Aerial view of Site 172, an unnamed creek flowing into Tuckers Slough, 8 April 1981. Observation point 1 km upstream from mouth.

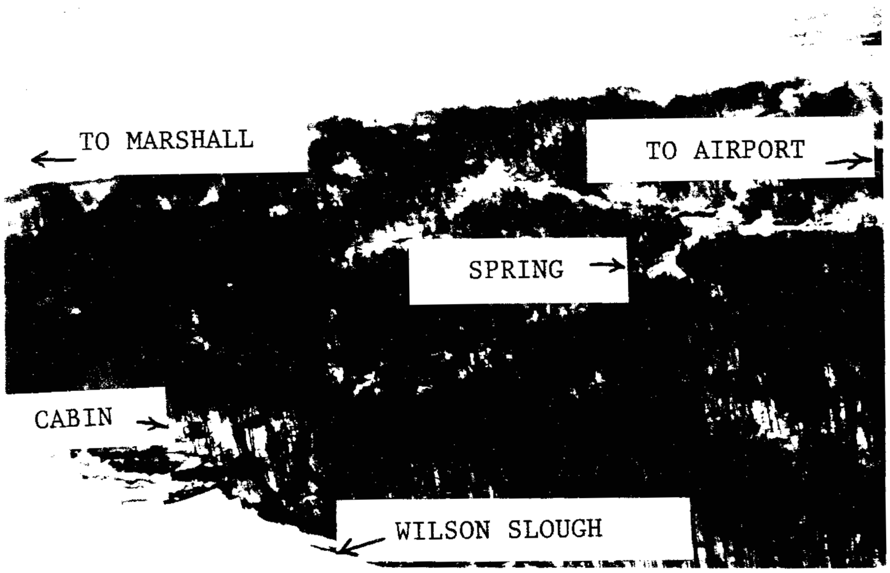
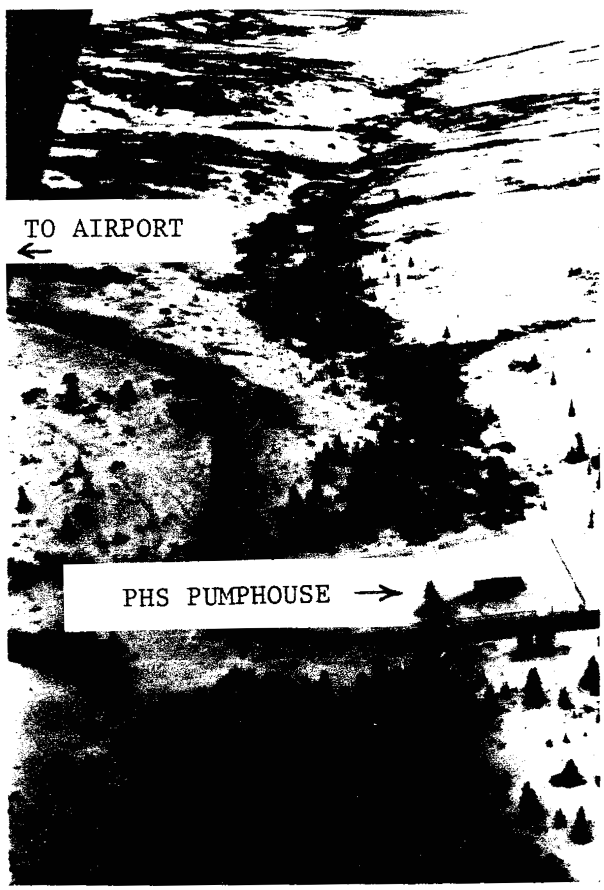


Figure 10. Aerial view of Marshall Airport Spring (Site 185), 11 March 1981.

Figure 11. Downstream view of Marshall Airport Spring (Site 185) outlet creek approximately 2 m below the source. 16 October 1980.

Figure 12. Aerial view of Alstrom Slough Creek (Site 194), 8 April 1981.



Emmonak. Availability of fresh ground water is unknown. The village uses treated river water. No springs are known near Emmonak.

Kotlik (Site 221). Availability of fresh ground water is unknown. No springs are known near Kotlik. The Pastolik River, approximately 25 km east of Kotlik, may be spring-fed, but we were unable to verify this.

Local Opinions Concerning Salmon Enhancement

A summary of comments on salmon enhancement in the LYR is given below by village.

Allakaket. The Allakaket Village Council (1981) favored salmon enhancement and has contacted FRED in the past regarding a village-run chum salmon fry release program to increase subsistence harvests. After learning about our hatchery site investigation, the Council expressed an interest in a state-run program to enhance the wild salmon stocks in the area. The Council recommended that the fall chum salmon run, which spawns in the South Fork (Koyukuk River) below the mouth of the Jim River, be enhanced through spawning channel construction, streamside incubators or egg plants. The fall run of chum salmon is considered to have a better quality than the summer run.

The Village Council was not opposed in principle to a commercial fishery but felt that there were not enough salmon to support even the subsistence fishery. In addition, they considered the quality of the salmon to be marginal by the time they reached Allakaket.

The Council was concerned about possible management, disease and genetic problems associated with a salmon hatchery on the Koyukuk River. Before the Village Council makes any commitment regarding salmon hatchery development in their area, it would prefer to observe developments at the Sikusuilaq Hatchery on the Noatak River, especially after full production is achieved and the impact of the hatchery on the wild chum salmon stocks can be evaluated.

Because of a perceived shortage of subsistence fish and a concern that subsistence hunting will some day be restricted, the Council was interested in developing new food sources. The Council suggested that FRED Division consider a white fish stocking program in the Alatna River and nearby lakes to provide a winter fishery.

Hughes. We were unable to visit Hughes or obtain local comments regarding salmon enhancement in the Hughes area. However, we heard from others in Huslia and Galena (Al Yatlin, personal communication; Carol Huntington, personal communication), that Hughes residents were concerned about the lack of sheefish in the Koyukuk River and had expressed an interest in a state-run sheefish enhancement program. (Some Hughes residents attributed the poor 1980 sheefish catches to a FRED Division egg take. This was unlikely since only 12 fish were taken).

Huslia. Villagers felt that the existing chum and chinook salmon fishery was not large enough to support subsistence needs (Al Yatlin, personal communication). They also felt that the quality of salmon reaching Huslia was poor. They were interested in salmon enhancement provided that (a) the salmon fishery continues to be managed as a subsistence fishery until run size is adequate for both subsistence and commercial use, (b) all potential disease, genetic and management problems are resolved, (c) hatchery produced salmon have acceptable flesh quality, and (d) hatchery production will not damage the existing wild salmon stocks.

The villagers might be more interested in the enhancement of whitefish than salmon, partly because of the above salmon problems and partly because whitefish were traditionally an important food source (Al Yatlin, personal communication). Several nearby lakes[1] were once used for winter whitefish fisheries. Why these lakes are no longer productive is not known, but overfishing and natural eutrophication are two possible causes.

Tanana. Steve Schwab, the city manager, felt that the local residents would favor hatchery development because they feel it would increase the village's economic base. He is trying to promote a regional approach to hatchery development with other villages (including Kaltag, Galena, Ruby and Eagle). To avoid regional struggles for the location of a facility, he would prefer to see it located near Eagle, or at least above the major villages, so that the hatchery's benefits could be shared by everyone.

Two people expressed an interest in developing a whitefish incubation and rearing facility (Fred Jordan and Pat Moore, personal communications). For release sites they suggested Fish Lakes, Twin Lakes, Hays Slough and several deep lakes near Palisades.

Ruby. The village favored hatchery development, especially if the site is located upriver from Ruby (Don Honea, personal communication). The village corporation would negotiate a land deal if a suitable site were found and if the Legislature provided the money.

---

1. Five lakes were suggested: Long Lake, Whitefish Lake, an unnamed lake sometimes called Whitefish Lake located approximately 4.8 km S.S.E. of Crow Lake, and two small lakes directly west of Grass Lake (which has apparently filled in). In the past, Long Lake was heavily fished.

Galena. Galena commercial fishermen are interested in hatchery development, primarily to enhance chinook and fall chum salmon (John Stam, personal communication).

Nulato. Twelve residents including the mayor, Fred Stickman, Jr., met with one of us (R. M.) to discuss salmon enhancement. Most of those present were in favor of hatchery development, but they were uncertain whether suitable locations were nearby.

Kaltag. Fourteen residents including the mayor, many of whom were village council members, met with one of us (R. M.) to discuss salmon enhancement. They expressed an interest in having a hatchery built to maintain the presently high commercial and subsistence harvest levels for chinook and fall chum salmon. They felt that the existing summer chum salmon run did not need enhancement.

However, before endorsing hatchery development, they wanted assurance that (a) hatchery stocks would not adversely effect the management of existing runs, (b) hatchery fish would have the same flesh and oil quality as natural stocks, (c) local hire would be used if a hatchery were to be built near their village, and (d) if they eventually developed a reliance on a government-run hatchery, the government would not slowly take away their subsistence fishing privileges.

Grayling. Several residents expressed an interest in salmon enhancement, especially at a location upriver from Grayling. However, before they would support a hatchery in their region, they wanted assurance that hatchery fish would have the same quality as wild fish.

Anvik. If a hatchery were built, residents would like to see it produce chinook salmon (Calvin Chase, personal communication). However, several villagers were concerned with possible adverse effects that a local hatchery might have on the Anvik River wild salmon stocks.

Holy Cross. All questions were referred to the mayor who was not available.

Russian Mission. Each of seven residents contacted expressed an interest in hatchery development. They were most interested in increasing the chinook salmon run but were also interested in enhancing the summer chum salmon run if their quality would be good.

Marshall. Village fishermen felt that the existing chinook salmon catch was inadequate and would like to see the king salmon run enhanced (Dave Cooper, personal communication). They felt that the summer chum salmon catch was adequate.

St. Mary's. Each of eight residents contacted indicated that the village favors expanding the commercial fishery, especially the chinook salmon fishery. A few were concerned about possible adverse effects a local hatchery might have on the wild salmon in the Andreafsky River.

The mayor indicated that village fishermen would prefer the enhancement of chinook or possibly sockeye salmon over chum salmon. The mayor also felt that hatcheries in the LYR may help prevent a perceived subsistence fish shortage if the subsistence preference law is repealed (Tim Troll, personal communication).

Mountain Village. Each of five residents contacted indicated that the village would favor salmon enhancement if the facility were located upriver from Mountain Village. Chinook and coho salmon were the preferred species. Two of those residents contacted wanted to see an uncompleted hatchery, built in Mountain Village by the Lower Yukon/Kuskokwim Regional Aquaculture Association, become operational.

Emmonak. A fish processor (Bodey 1980) and fishery management biologist (Geiger 1980), both working in Emmonak, saw little promise for a hatchery in the Yukon River Delta.

Kotlik. Of the nine residents contacted, none expressed a strong opinion either for or against hatchery development. Two residents stated that if a hatchery were built, they would prefer to see it produce chinook salmon since the price of chum salmon is lower and is expected to drop further.

DISCUSSION

Hatchery Site Observations.

Chum salmon appear to be the salmon species best suited for enhancement in the LYR because they require only short-term rearing. The Yukon River has two runs of chum salmon, a summer run and a fall run. Yukon and Koyukuk River fishermen generally prefer the fall run because they consider its quality better. From an enhancement point of view, the fall run is also the better run to work with because it has an incubation period approximately 3 months shorter than that of the summer run.

Chinook and coho salmon are also important in the LYR, but because of their long rearing requirements (one year for chinook salmon and two years for coho salmon), these species appear to be unsuited for production at a remote facility. Chinook salmon may have some potential, however, in cases where only surface water is available (see below).

Four recurring problems were found to confront hatchery development in the LYR.

1. Low water temperatures. Surface water temperature remain near $0^{\circ}C$ from October to April and thus cannot be used for chum salmon incubation or rearing without heating. Existing chum salmon spawning grounds are located in slightly warmer spring areas and these areas are generally inaccessible.

2. Poor aquifers. Permafrost, soil structure, and the slow recharging of aquifers in winter limit the amount of water that can be drawn from wells and springs to 150 lpm or less. Water flows generally reached their minimum in March and April when the water requirements of a hatchery begin to increase.

3. Poor water quality. Ground water in the LYR is characterized by high iron content (typically 0.3 to 15 ppm), high manganese content (0.05 to 1.5 ppm) and high alkalinity (200 to 500 ppm $CaCO_3$).

4. Poor access. Most of the LYR is remote. Only the villages and sites along the Haul Road are accessible year-round. However, most of the airstrips are short and lack navigational aides. Sites on the major rivers and the few other roads that are in the region are accessible in the summer only.

Many considerations are involved in hatchery site selection besides water and access, such as impact on existing fisheries (see below), land status and gravel availability. However, our investigation concentrated on satisfying the water and access criteria since they were viewed as the most severe. Fifteen of the 215 sites investigated that came closest to satisfying these criteria were selected as sites worthy of further consideration.

Although these sites were the most promising ones that we found, their water supplies and accessibility are still far from ideal.

Water flows and temperatures for these sites are given in Table 4. Table 4 also estimates the fall chum salmon egg capacities that the water supplies at each site might support in a single-pass hatchery (a hatchery in which the water is used only once). The egg capacities were based on calculations appearing in Appendix A. Information on access and gravel availability at these sites is given in Appendix Table 5.

Of the 15 potential sites, only three (Horner Hot Springs, Melozi Hot Springs and a spring-fed tributary of the Dietrich River) were found that could support a single-pass hatchery with a capacity of more than 1 million eggs. However, each has its drawbacks. The water quality at Horner Hot Springs (site 115) has not been carefully examined and the nearest airstrip is at Ruby, 37 km away. Water availability is limited and would restrict a single-pass hatchery to 3 million eggs. Melozi Hot Springs (site 130) has enough water to incubate about 20 million eggs in a single-pass hatchery. However, Melozi Hot Springs Creek is one of the major chum salmon spawning tributaries of the Melozi River and potential conflicts may develop. Also, Melozi Hot Springs is not accessible by barge from the Yukon River. The Dietrich River spring (site 4) has not been observed long enough to determine its reliability. Water availability is limited and would restrict a single-pass hatchery to 1.5 million eggs. This site would provide salmon only in the Koyukuk River and in the Yukon River below the mouth of the Koyukuk.

If a hatchery is to be built in the LYR it would be better to locate it at or near a village since this would greatly reduce construction and operational costs. However, the water sources available at most villages are limited. For this reason a separate study was begun (Raymond 1981) to evaluate the feasibility of incubating salmon eggs with recirculating water. Additional testing of recirculation is needed, but it is expected that a small-scale hatchery could be operated for educational or experimental purposes in many of the villages investigated. A water source of only 10 lpm may be capable of incubating more than 1 million eggs. Table 4 shows the potential egg capacities at most of the fifteen most promising sites if recirculation is used. These figures are based on using 95% recirculated water and 5% new water (5% make-up). As shown in Table 4, most sites are capable of incubating several million eggs if recirculation is used.

We may have overlooked additional sites in remote parts of the Yukon drainage, but because of their remoteness, these sites would probably be uneconomical to develop. If a search for hatchery water supplies in the LYR is to continue, perhaps a more fruitful place to look is the sub-permafrost layer at one or more of the Yukon River villages where more abundant and better quali-

Table 4. Minimum water flows and temperatures, and fall chum salmon egg capacities of sites in the Lower Yukon River region having the most potential for hatchery development. Egg capacities are given for a single-pass hatchery (S.P.) in which none of the water is recirculated and a recirculating hatchery (Recirc.) in which 95% of the water is recirculated. Egg capacities are calculated in Appendix A.

Name (site #)	Flow (lpm)	Temp. (°C)	Egg Capacity (millions) S.P.	Recirc.
Dietrich River (1)	5,000	0.0	0.3	5.4
Spring near Dietrich R. (4)	200	8.1	1.2	24.5
Jim River Bridge #3 (23)	89,000	0.0	0.3	5.4
Clear & Caribou Cks (54, 55)	?	?		
Horner Hot Spring (115)	170	48.0	3.4	67.2
Ruby PHS well (120)	81	0.5	0.2	4.3
Midnight Creek Spring (128)	710	1.2	0.4	8.2
Melozi Hot Spring (130)	492	56.0	21.0	420.0
Holy Cross Spring (167)	71	1.6	0.2	3.8
Holy Cross PHS well (170)	90	2.4	0.2	4.8
Unnamed Crk. near (172) Dogfish Village	?	?		
Russian Mission (176) PHS well	110	3.6	0.3	5.8
Marshall Airport Spring (185)	14	1.1	0.04	0.7
St. Mary's Mission well (193)	7	?	0.02	0.4
Alstrom Slough Creek (194)	290	0	0.3	5.4

ty water may be available. Most of the existing wells in these villages are under 70 m in depth. A 170 m deep experimental well in Bethel obtained water with a much lower iron concentration than that found in water from shallower wells. This well has been producing 570 lpm at 0.6°C (Hal Borrego, personal communication).

Although the preceding discussion pertained primarily to chum salmon, chinook salmon might be considered for enhancement in certain cases. Chinook salmon, unlike the other species, do not appear to require springs to successfully spawn. Chinook salmon eggs and alevins appear to compensate for the colder winter temperatures by remaining in the gravel for a longer period (from about mid-July to early June). Thus in areas having only surface water, a chinook salmon hatchery might be possible. As was mentioned previously, it is probably uneconomical to keep chinook salmon fry for a full year in a remote facility. However, one might avoid a large part of the rearing and holding costs by releasing the chinook salmon as fingerlings in the fall before freeze-up. Salmon fingerlings do not feed actively at low temperatures and so the hatchery fingerlings would probably not compete strongly with wild salmon fingerlings during the following winter. It should be noted, however, that surface waters are more likely to contain pathogens and silt than well water or springs, and for this reason are avoided when possible by fish culturists.

Local Opinions Concerning Salmon Enhancement

In recent years salmon harvests in the LYR have been relatively high. Consequently, not many requests have been received by FRED Division to look into salmon enhancement. This may be partly because many fishermen in the region are not familiar with hatcheries. However, their awareness of hatcheries is increasing. Also, there is an increasing demand by middle and upper Yukon River fishermen for expanding the commercial fisheries in their areas. Although these fishermen primarily want a greater allocation of the Yukon River's wild salmon stocks (at the expense of the Lower Yukon River fishery), it is possible that they will look to hatcheries as a solution to their problem.

Although we did not find a "grass roots" movement for salmon enhancement in the LYR, when fishermen were asked about salmon enhancement, most expressed an interest in it. Opinions varied from village to village on the species that most needed enhancement. Below Anvik, fishermen most often expressed an interest in enhancing the chinook salmon run. On the Yukon River above Anvik fishermen were mostly interested in enhancing the fall chum and chinook salmon runs. On the Koyukuk River, fishermen were most interested in fall chum salmon and whitefish.

Although most fishermen appeared to approve of hatchery-produced fish, many subsistence fishermen living in upriver locations tended to favor rehabilitation of existing runs without using hatcheries. This is partly the result of their concern that the quality of hatchery-produced fish may not be as high as that of wild fish. (Although the muscle tone of hatchery and wild salmon fry probably differ, we are unaware of any differences in the adults). Subsistence fishermen may also be uncomfortable with the concept of subsisting on fish that aren't naturally produced.

Some fishermen in upriver villages were concerned that an expansion of the commercial fishery caused by a salmon enhancement program might increase their dependence on a cash economy. This, they fear, might lead certain government agencies that are opposed to subsistence to reduce their subsistence hunting and fishing priviledges. Although this possibility can't be ruled out, we suspect that a hatchery would do more to strengthen the subsistence fishery than to weaken it.

If a production-scale hatchery is to be built, most LYR fishermen wanted it to be located upriver from their village. This provides an opportunity to consider sites upriver from the region studied. Two sites that have excellent water and access and that would easily support production goals are the existing Clear Hatchery at Clear Air Force Station and the mouth of the Delta River near Delta Junction. However, problems arising from interactions between hatchery and wild stocks would have to be resolved before these sites could be seriously considered.

General Considerations Concerning Salmon Enhancement in the Lower Yukon River Region

Impacts on Existing Fisheries. We did not investigate potential impacts of a hatchery on wild salmon stocks in the LYR because we felt that the impacts would depend entirely on the site and type of enhancement chosen. However, the general concerns can be described. The potentially most serious impact is overfishing. The optimum harvest for hatchery-produced salmon can be 90% or more of the run. Wild stocks, however, generally can't withstand harvests averaging more than 60% (the optimum harvest varies from year to year depending on the strength of the run). Thus, the possibility of overharvesting the wild stocks exists in those parts of the river where the hatchery and wild stocks are mixed.

Hatchery-produced salmon fry will also compete with, and in some cases prey on, wild salmon fry. The importance of competition and predation will depend on the species and size of the released fish and the timing and location of the release.

A fraction of hatchery-produced fish (perhaps as much as 25% for chum salmon and 5% for chinook and coho salmon) will stray from the hatchery and interbreed with wild stocks. Some people feel that hatchery fish are not as genetically fit as wild fish because of the removal of natural selection pressures in the hatchery.

Hatchery fish may also carry diseases that occasionally break out in hatcheries (because of the intensive culture methods that are used there). Thus, interbreeding may result in a weakening of the wild stock's gene pool and the infection of the wild stock with disease. However, there is little evidence that either of these impacts have occurred elsewhere.

Each of the above impacts can be reduced by locating a hatchery as far as possible from major salmon spawning grounds.

Benefit/Cost Analysis. Although an accurate benefit/cost analysis for a hatchery in the LYR can't be made without choosing a specific site, some rough estimates for generalized sites can be useful. Table 5 shows estimates for the various costs and the egg capacities required for a benefit/cost ratio of 1 for hatcheries at three types of sites: a village, a remote site more than 10 km from a village but having barge access, and a site on the Haul Road. The construction and operational costs are based on those encountered for the Clear and Sikusuilaq Hatcheries, also in Northern Alaska. The high egg capacity required for a remote site (38 million) makes it much less attractive than a village site (22 million) or Haul Road site (19 million). Of course, these figures assume that a suitable water supply is available at each site.

A hatchery's economic benefits do not necessarily have to exceed its costs for it to be feasible, since the hatchery may have an

Table 5. Estimates of costs and the egg capacity required to provide a benefit/cost ratio of 1 at 3 types of site in the Lower` Yukon River region.

Site	Costs (x \$1,000)				Egg Capacity (millions) For a B/C=1[2]
	Constr.	Yearly Payment[1]	Oper.	Total Yearly	
major village	4,000	424	300	724	22
remote site	8,000	848	400	1,248	38
Haul Road	3,000	318	300	618	19

1. Based on a 30 year loan at 10%.
2. Based on a 1% return to fishery, 65% harvest and a value of \$5/fish. This is equivelent to a value of 3.25¢ per egg.

educational or scientific value. In many villages the educational value may be greater than the economic value.

Non-hatchery Enhancement. There are other types of salmon enhancement besides hatchery production. Most of them, however, are not suited for the LYR. One method, instream incubation, involves placing an egg incubator on a river bank and diverting some of the water through it. An instream incubator must (1) be accessible for periodic inspections, (2) have a water supply at the right temperature (3) remain ice-free in the winter and (4) be located in an area that won't flood or dry up. We do not know of any sites in the LYR that have these characteristics. Planting of eyed eggs is another enhancement method which involves incubating salmon eggs in a facility for 1 to 2 months until they reach the eyed stage. The eyed eggs are then planted in a stream bed before freeze-up. The disadvantages of this method are that it requires construction of an incubating facility that is used for only a small part of the year, and that evaluation of the egg plant's effectiveness is very difficult to obtain. Spawning habitat improvement is a third type of enhancement that includes removing beaver dams and log jams and rechanneling some streams to improve spawning areas. Because of the remoteness of most of the spawning sites in the LYR, we are unaware of opportunities for spawning habitat improvement.

ACKNOWLEDGMENTS

We thank the many residents in the Yukon and Koyukuk River villages who contributed to this study for their assistance and hospitality. We also thank Calvin Skaugstad for his assistance with the Haul Road investigations and the U.S. Public Health Service in Anchorage for the detailed information they provided.

CONCLUSIONS

1. The fall chum salmon run appears to be best suited for enhancement in the LYR.

2. Fifteen locations in the LYR were identified as potential sites for small-scale (1-5 million egg capacity) fall chum salmon hatcheries.

3. Because of limited water supplies or access limitations, no sites were found that would accomodate a production-scale (>10 million egg capacity) hatchery.

4. Water supplies at several villages are so limited that even a small-scale hatchery would not be possible without recirculation. Recirculation technology needs further development before it can be used in the LYR.

5. More abundant and better quality water may be available at some villages from below the permafrost layer. Exploratory drilling would be required.

6. Chinook salmon might also be produced in a hatchery in the LYR if a fall release is feasible and if water quality problems associated with using surface waters can be solved.

7. Although many fishermen expressed an interest in salmon enhancement when they were interviewed, we did not find a spontaneous demand for it. This was in part due to the fishermen's unfamiliarity with salmon enhancement concepts.

8. There is a strong need for education of Yukon River fishermen on salmon biology and salmon enhancement techniques. A small-scale educational hatchery placed in one or more villages would do much to satisfy this need.

9. It is likely that there will be a stronger demand for hatchery production in the future as Yukon River fishermen become more familiar with hatchery methods and as competition for the allocation of wild salmon between upper and lower Yukon River fishermen increases.

10. If a production-scale hatchery is to be built, most LYR fishermen wanted it to be located upriver from their village. This provides an opportunity to consider sites upriver from the region studied.

REFERENCES

Alaska Department of Environmental Conservation. 1980a. Public water supply water quality computer printout. R01-18F-6890. Juneau, AK.

__________. 1980b. Unpublished file data. Fairbanks, AK.

Alaska Department of Fish and Game. 1980. Commercial Fisheries Division annual management report, 1980, Yukon Area. Fairbanks, AK.

__________. 1977. Preliminary Alaska Department of Fish and Game water quality standards for salmon aquaculture. Fisheries Rehabilitation, Enhancement and Development Division. Juneau, AK.

Allakaket Village Council. 1981. Proceedings from the 5 February 1981 Village Council Meeting. Mayor Pollock Simon presiding. Allakaket, AK.

Andersen, Fred. Personal communications. Mr. Andersen is the Yukon Area Biologist, Alaska Department of Fish and Game, Division of Commercial Fisheries. Fairbanks, AK.

Anderson, G. S. 1970. Hydrological reconnaissance of the Tanana Basin, central Alaska. U.S. Geological Survey Hydrologic Inventory, HA-319. Anchorage, AK.

Anonymous. 1975. As-built report, water well at Koyukuk Village safe water facility, Koyukuk, Alaska. Dickinson, Oswald, Walsh and Lee Consultant Engineers. Anchorage, AK.

Anonymous. 1980. Project summary, sanitation facilities construction, City of Tanana. Project No. AN-81-231. U.S. Public Health Service, Indian Health Service. Anchorage, AK.

Bainbridge, Steven T. 1977a. Water well analysis - sanitation facilities construction, Marshall, Alaska. Project No. AN-75-110. U.S. Public Health Service, Alaska Area Native Health Service. Anchorage, AK.

Bainbridge, Steven T. 1977b. Water well analysis - sanitation facilities construction, Shageluk, Alaska. Project No. AN-75-149. U.S. Public Health Service, Alaska Area Native Health Service. Anchorage, AK.

Bainbridge, Steven T. 1977c. Water well analysis - sanitation facilities construction, Mt. Village, Alaska. Project No. AN-76-155. U.S. Public Health Service, Alaska Area Native Health Service. Anchorage, AK.

Bainbridge, Steven T. 1977d. Water well analysis - sanitation facilities construction, St. Mary's, Alaska. Project No. AN-73-932 and 76-143. U.S. Public Health Service, Alaska Area Native Health Service. Anchorage, AK.

Bainbridge, Steven T. 1977e. Water well analysis - sanitation facilities construction, Pilot Station, Alaska. Project No. AN-70-910. U.S. Public Health Service, Alaska Area Native Health Service. Anchorage, AK.

Bainbridge, Steven T. 1977f. Water well analysis - sanitation facilities construction, Grayling, Alaska. Project No. AN-77-177. U.S. Public Health Service, Alaska Area Native Health Service. Anchorage, AK.

Bainbridge, Steven T. 1978. Water well analysis - sanitation facilities construction, Anvik, Alaska. Project No. AN-77-6250. U.S. Public Health Service, Alaska Area Native Health Service. Anchorage, AK.

Bainbridge, Steven T. 1979. Water well analysis - sanitation facilities construction, Pilot Station, Alaska. Project No. AN-78-815. U.S. Public Health Service, Alaska Area Native Health Service. Anchorage, AK.

Baker, Bob. 1977. Site selection criteria for supplemental salmon production. Alaska Department of Fish and Game. Fisheries Rehabilitation, Enhancement and Development Division. Anchorage, AK. (unpublished).

Bodey, Bill. 1980. Tundra Drums. 7 August 1980. Pg. 23. Mr. Bodey is the owner of Bering Sea Fisheries in Sunshine Bay, near Emmonak, AK.

Brown, Andrew. Personal communication. Mr. Brown is a member of the Lower Yukon ADF&G Advisory Committee. Mt. Village, AK.

Boots, Charlie. Personal communication. Mr. Boots is the plant operator for the U.S. Public Health Service Water Plant. Russian Mission, AK.

Borrego, Hal. Personal communication. Mr. Borrego is a co-owner of Bethel Utilities. Bethel, AK.

Brumbaugh, Mark. 1977. Water well analysis - sanitation facilities construction, Tanana, Alaska. Project No. AN-76-621R. U.S. Public Health Service, Alaska Area Native Health Service. Anchorage, AK.

Changsak, Leroy. Personal communication. Russian Mission, AK.

Chase, Calvin. Personal communication. Mr. Chase is the subregional director of Dena Aka, Inc. Anvik, AK.

Cooper, Dave. Personal communication. Mr. Cooper is a former U.S. Public Health Service Employee, commercial fishermen, and local resident. Marshall, AK.

Deacon, Henry. Personal communication. Mr. Deacon is the maintainance foreman at Grayling Day School. Grayling, AK.

Egan, Dan. Personal communication. Mr. Egan is the owner of Alaska Gold Company which has an active placer claim near Hogatza, AK. Fairbanks, AK.

Erhart, Lester. Personal communication. Mr. Erhart is a commercial fisherman. Tanana, AK.

Folger, Ray. Personal communication. Mr. Folger is a commercial/subsistence fisherman. Tanana, AK.

Geiger, Mike. 1980. Tundra Drums. 21 August 1980. Pg. 18. M. Geiger is the Yukon Area Biologist, Alaska Department of Fish and Game, Division of Commercial Fisheries. Anchorage, AK.

Gerlek, Steve. Personal communication. Mr. Gerlek is a U.S. Public Health Service employee. Anchorage, AK.

Hart, Betsy. Personal communication. Ms. Hart is co-owner of the Ruby Roadhouse. Ruby, AK.

Honea, Don. Personal communication. Mr. Honea is the vice president of the Ruby Native Council. Ruby, AK.

Huntington, Carol. Personal communication. Ms. Huntington is a former Alaska Department of Fish and Game, Subsistence Section employee. Galena, AK.

Jordan, Fred. Personal communication. Mr. Jordan ia a subsistence fisherman. Tanana, AK.

Jujan, Stan. Personal communication. Mr. Jujan is the administrator for the Kotlik REAA School. Kotlik, AK.

Justin, Stan. Personal communication. Mr. Justin is an Alaska Department of Environmental Conservation, Village Safe Water Program employee. Fairbanks, AK.

Kangas, Albert. Personal communication. Mr. Kangas is the owner of the Ruby Mining Company and a long time Ruby resident. Ruby, AK.

LaVine, Larry. Personal communication. Mr. LaVine is a U.S. Geological Survey employee. Anchorage, AK.

Linford, Sherry. 1979. Water well analysis - sanitation facilities construction, Russian Mission, Alaska. Project No. AN-78-199. U.S. Public Health Service, Alaska Area Native Health Service. Anchorage, AK.

Louden, Father. Personal communication. Father Louden is the administrator of St. Mary's Mission. St. Mary's, AK.

Madros, Franklin. Personal communication. Mr. Madros is the mayor of Kaltag, AK.

Madros, Leon. Personal communication. Kaltag, AK.

Mike, Joseph. Personal communication. Mr. Joseph is the mayor of Kotlik, AK.

Miller, Thomas. Personal communication. Mr. Miller is a U.S. Geological Survey employee. Anchorage, AK.

Miller, T. P. 1973. Distribution and chemical analysis of thermal springs in Alaska. U.S.G.S. Open File Report #570. U.S. Geological Survey. Anchorage, AK.

Miller, T. P., I. Barnes and W. W. Patton, Jr. 1973. Geologic setting and chemical characteristics of hot springs in central and western Alaska. U.S.G.S. Open File Report #575. U.S. Geological Survey. Anchorage, AK.

Moore, Pat. Personal communication. Tanana, AK.

Phillip, Patrick. Personal communication. Mr. Phillip is the mayor of Alakanuk, AK.

Pope, Douglas. 1980. The Upper Yukon and other freshwater salmon fisheries: findings, conclusions and recommendations. Report to the Eleventh Alaska Legislature.

Polty, Nick. Personal communication. Mr. Polty is a member of the Lower Yukon ADF&G Advisory Committee. Russian Mission, AK.

Ray, Stanzer. Personal communication. Mr. Ray is an Upper Tozitna River Resident. Tanana, AK.

Raymond, J. 1977. Salmon enhancement preference of Yukon fishermen. Alaska Department of Fish and Game, Fisheries Rehabilitation, Enhancement and Development Division. Fairbanks, Ak.

Raymond, J. 1979. Trip Report, March 29 to 30. Alaska Department of Fish and Game, Fisheries Rehabilitation, Enhancement and Development Division. Fairbanks, AK.

Raymond, J. 1981. First test of a recirculating salmon incubator for Alaskan villages with limited water supplies. Alaska Department of Fish and Game, Fisheries Rehabilitation, Enhancement and Development Division. Fairbanks, AK.

Schwab, Steve. Personal communication. Mr. Schwab is the city manager. Tanana, AK.

Shaw, Johnny. Personal communication. Mr. Shaw is the principal of Grayling Day School. Grayling, AK.

Sloan, Charles, C. Zenone and L. Mayo. 1975. Icings along the trans-Alaska pipeline route. U.S.G.S. Open File Report #75-87. Anchorage, AK.

Snyder, Dick. Personal communication. Mr. Snyder is a U.S. Geological Survey employee. Anchorage, AK.

Stam, John. Personal communication. Mr. Stam is the chairman of the Galena ADF&G Advisory Committee. Galena, AK.

Stevens, Don. Personal communication. Mr. Stevens is a member of the Lower Yukon ADF&G Advisory Committee. St. Mary's, AK.

Stevens, Richard. Personal communication. Mr. Stevens is a para-planner for the Allakaket Village Council. Allakaket, AK.

Stickman, Fred, Jr. Personal communication. Mr. Stickman is the Village Council President. Nulato, AK.

Swan, Bill. Personal communication. Mr. Swan is a co-owner of Swan Drilling Company. Fairbanks, AK.

Troll, Tim. Personal communication. Mr. Troll is the city manager for St. Mary's, AK.

Tumuwak, Victor. Personal communication. Mr. Tumuwak is the Village Council President. Kotlik, AK.

Turner, D., R. Forbes, M. Albanese, J. MacBeth, A Lockhart and S. Seed. 1980. Geothermal energy resources of Alaska. Report to the Division of Geothermal Energy, U.S. Department of Energy. Geophysical Institute, University of Alaska. Fairbanks, AK

U.S. Federal Aviation Administration. FAA Form 5010-1. Airport Master Records.

U.S. Fish and Wildlife Service. 1962. Fish and wildlife resources of the Yukon River basin (Anvik to Marshall). Progress Report No. V. Anchorage, AK.

U.S. Geological Survey. 1957. Quantity and quality of surface waters of Alaska, October 1953 to September 1956. Geological Survey Water Supply Paper #1486. Anchorage, AK.

__________. 1958. Quantity and quality of surface waters of Alaska, October 1956 to September 1957. Geological Survey Water Supply Paper #1500. Anchorage, AK.

__________. 1960. Quantity and quality of surface waters of Alaska, October 1958 to September 1959. Geological Survey Water Supply Paper #1640. Anchorage, AK.

__________. 1961. Quantity and quality of surface waters of Alaska, October 1959 to September 1960. Geological Survey Water Supply Paper #1720. Anchorage, AK.

__________. 1968. Water resource data for Alaska, Water Year 1967. Geological Survey Water - Data Report AK-67-1. Anchorage, AK.

__________. 1977. Water resource data for Alaska, Water Year 1976. Geological Survey Water - Data Report AK-76-1. Anchorage, AK.

__________. 1978. Water resource data for Alaska, Water Year 1977. Geological Survey Water - Data Report AK-77-1. Anchorage, AK.

U.S. Public Health Service. Unpublished file data. Office of Environmental Health. Anchorage, AK.

Waring, G. A. 1917. Mineral springs of Alaska. U.S.G.S. Water Supply Paper #418. U.S. Government Printing Office. Washington, D. C.

Webb, Joe. 1979. Fisheries inventory of the Melozitna River. U.S. Department of Interior, Bureau of Land Management. Fairbanks, AK.

Whato, Dave. Personal communication. Mr. Whato is a U.S. Public Health Service employee. Anchorage, AK.

Wheaton, Scott. 1980. Kaltag gallery site/tank foundation soils. U.S. Public Health Service, Alaska Area Native Health Service. Anchorage, AK. (unpublished).

Wilde, Henry. Personal communication. Mr. Wilde is a member of the Lower Yukon ADF&G Advisory Committee. Mt. Village, AK.

Yatlin, Al. Personal communication. Mr. Yatlin is the Village Corporation Land Manager. Huslia, AK.

Young, George. 1977. Survey of the Archuelinguk River, 24 April 1977. Esca-Tech Corporation. Anchorage, AK. (unpublished).

APPENDIX A

Egg capacities of hatcheries with different water supplies

Assume that a water source has a flow q and an average temperature T. Let Q = the water flow that can be obtained at a site at 3.5°C without expending additional energy. There are two cases to consider depending on the temperature.

1. $T < 3.5°C$. The water must be heated with waste heat to allow for proper egg development. The recoverable heat output of a diesel-electric generator (used for providing electric power to a hatchery) is approximately equal to its electric power output. A 25 KW generator will therefore generate 357 kcal/min. One kcal will raise the temperature of one liter of water by 1°C. The maximum flow Q_m that can be heated to 3.5°C is

$$Q_m = \frac{357}{3.5 - T} \text{ liters per minute}$$

If $Q_m < q$, then $Q = Q_m$. If $Q_m > q$, then $Q = q$.

2. $T > 3.5°C$. There are four sites in Table 4 with $T > 3.5°C$. Each site has a nearby water source (0°C in winter) that can be mixed with the spring water to lower it to 3.5°C. The resultant flow is then

$$Q = qT/3.5.$$

Horner Hot Spring is an exception to this rule since there is not enough cold water to cool the hot water. For this case, Q = the cold water flow (1100 lpm) plus enough of the hot water (87 lpm) to provide a temperature of 3.5°C.

Now that we have an estimate for Q for each site, we may calculate the number of eggs that each site is capable of incubating. A flow of 378 lpm is required for each million eggs being incubated. The egg capacity of a single-pass hatchery (where the water is used only once), is therefore

$$C_s = Q/378 \text{ million eggs.}$$

For a hatchery using 95% recirculated water and 5% new water (5% make-up), the egg capacity is

$$C_r = 20C_s.$$

Appendix Table 1. Water availability, Haul Road Region, Lower Yukon River Hatchery Site Investigation. Letters in parentheses refer to additional data available in Volume II: C = water quality records; P = partial water quality records; W = well logs; D = aquifer draw down log. P/L MP is pipeline mile post. Entries not referenced attributable to this report.

Site #	Name	Date	Flow (liters/min)	Temp. ($^{\circ}$C)	Comments	Reference
1	Dietrich River	10/3/80	1,700	1.0	P/L MP 175.5.	
		3/30/79	5,100	0	P/L MP 180.8. Very clear, several open areas along road. (P)	1
		4/14/81	4,580	0.4	P/L MP 180.75. Clear, clean gravel. 4.5 m from road.	
2	Spring near Dietrich River	10/3/80	1,700	5.1	P/L MP 180.4 culvert. Spring on west side of road 6.0°C. Spring on east side 2.5°C. Both join on east side, 5.1°C. 70 m below confluence, 3.1°C.	
		4/14/81			Snowed over.	
3	Spring near Dietrich River	10/3/80		1.1	P/L MP 182.2.	
		4/14/81			Snowed over.	
4	Spring near Dietrich River	10/3/80	3,100	7.5 - 8.5	P/L MP 190.0 culvert. 7.5°C @ culvert, 8.5°C where culvert exits hill approx. 46 m upstream from culvert. Algae present.	
		4/14/81	200	7.7 - 8.1	4.5°C @ culvert, 7.7 to 8.1°C 50 m upstream above culvert. pH 6.43, D.O. 3.5 ppm, hardness 23 grains/gal, 76.2 mm sculpin	
5	Spring near Dietrich River	10/3/80	84	10.0	108 APL - 1B, P/L MP 179.5. Pipeline buried within a few meters. High temp. may be due to proximity.	
		4/14/81			Snowed over.	
6	Spring near Atigun River Bridge #1	10/3/80	2,200	11.5	Pipeline buried very near this site. High temp. may be due to proximity.	
7	Atigun Camp Creek	10/3/80	4,400	2.0	Located @ south end of Atigun Camp. Temp. @ culvert 1.9°C. Temp. @ source 400 m upstream 2.0°C.	

Appendix Table 1 continued.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
8	Spring near Atigun River	10/3/80	850	2.8	OMS 112-3.2 culvert. 2.8°C @ source 9 m from culvert. At culvert 2.4°C.	
9	Possible spring near Atigun Camp				P/L MP 209.5. Small hillside icings form along west flank of Sukakpak Mtn.	2
10	Middle Fork Koyukuk River at Bridge #1	3/30/79	59,500	0	Very clear, 1.5 meter ice, (P)	1
		10/3/80		1.3		
		4/14/81			Some open water upstream.	
11	Middle Fork Koyukuk River at Bridge #2	3/30/79	2,200		Very clear, open water in small area below bridge.	1
		4/14/81			Open water below bridge.	
12	Middle Fork Koyukuk River at Bridge #3	4/14/81			Snow covered.	
13	Middle Fork Koyukuk River at Bridge #4	4/14/81	4,900	0.6	Open water, thin ice.	
14	Hammond River	4/14/81			Snow covered.	
15	Creek near Cold Foot	4/14/81			Immediately south of Cold Foot. Some open water downstream from culvert.	
16	Minnie Creek near Cold Foot	4/14/81			Snow covered.	
17	Slate Creek near Cold Foot	4/14/81			Snow covered.	
18	Gold Creek				P/L MP 215.8. Small icings form along a 300 m area upstream from Haul Road.	2
19	Sheep Creek				P/L MP 216.6. Small icings form upstream from Haul Road.	2

Appendix Table 1 continued.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
20	South Fork Koyukuk River at Haul Road bridge	3/30/79		0	Very clear, 1.2 m ice, 5 cm water under ice, 76 lpm upwelling through ice hole. (P)	1
		4/14/81			Ice 1.2 m thick.	
21	North Spring Creek				P/L MP 240.2. Small icings along spur dikes.	2
22	Twelve Mile Creek				P/L MP 243. Large icing on west side of Haul Road corridor.	2
23	Jim River Bridge #3	10/4/80		0.1		
		4/14/81			Open water along long leads. Pump intake in middle of river apparently in operation.	
24	Douglas Creek	4/14/81			Traversed lower 3.2 km. No open water, snow covered.	
25	Jim River Bridge #2	4/14/81			Snow covered, no open water or overflow.	
26	Jim River Bridge #1	3/30/79	3,400		Very clear, small area open water upstream from bridge.	1
		10/2/80	51,000	2.5	Clear, no ice, 2.3°-2.5°C, gravel bottom.	
		4/14/81	10,200		Open water.	
27	Jim River Spring #1 near Prospect	10/2/80	430	5.1	Clear, located near pumphouse.	
		4/13/81	280	0.5	Sampled 25 m downriver from pumphouse at Jim R. Camp. Open water area near riffles. Rest of channel frozen.	
28	Jim River at Prospect Camp	3/30/79	13,600	0	Very clear, river covered with overflow. (P)	1
		10/2/80	127,400	2.5	Clear, no ice.	
29	Creek flowing into Jim R.	10/4/80	850	1.9	East bank 800 m below Jim River Bridge #3 (JRB #3)	

Appendix Table 1 continued.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
30	Creek flowing into Jim R.	10/4/80	6,800	2.1	East bank 1.6 km below JRB #3	
31	Creek flowing into Jim R.	10/4/80	6,800	2.5	East bank 1.9 km below JRB #3	
32	Creek flowing into Jim R.	10/4/80	10,200	1.1	West bank 2.9 km below JRB #3	
33	Creek flowing into Jim R.	10/4/80	2,600	0.2	West bank 3.1 km below JRB #3	
34	Creek flowing into Jim R.	10/4/80	850	2.5	West bank 4.0 km below JRB #3. Appears to be spring fed from the river.	
35	Creek flowing into Jim R.	10/4/80	5,100	1.0	East bank 4.8 km below JRB #3. 61 m to Haul Road.	
36	Jim River Spring #2 near Prospect	4/13/81	630	0.3	800m below pumphouse on opposite side of river. Open water, algae present.	
37	Jim River Spring #3 near Prospect	4/13/81	1,600	0.25	180 m down from Jim R. Spring #2. Open water, lots of algae.	
38	Jim River near Prospect	4/13/81	89,200	0	3.4 km downstream from pumphouse. Open water near high gradient.	
39	Jim River near Prospect	4/13/81		0.7 - 0.9	Below beaver dam 30 m upstream from site #38. Open water immediately below beaver dam.	
40	Jim River near Prospect	4/14/81			2.6 km upstream from pumphouse. Several patches of open water typically 50 cm x 50 cm. Current audible through ice.	
41	Jim River near Prospect	4/14/81	85,000	0	4.3 km downstream from pumphouse. Many open leads. Snow too deep to continue.	
42	Unnamed creek, trib. of Jim R.	4/14/81	4,500	1.7	800 m south of Jim R. Bridge #3.	
43	Prospect Creek at Bridge	4/13/81			Snow covered. No overflow. Ice 90 cm thick under bridge.	
44	N. Fork Bonanza Creek at Haul Road bridge	4/13/81			Snow covered. No overflow visible.	

Appendix Table 1 continued.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
45	S. Fork Bonanza Creek at Haul Road bridge	4/13/81	7,400	0.7	3 m of open water 6 m above bridge.	
46	Fish Creek	10/2/80	28,400	1.6	P/L MP 295. Clear, gravel bottom.	
		4/13/81			Frozen nearly to bottom. Ice transparent at bridge. Faint current trickle audible.	

<u>Key to References for Appendix Tables 1, 2 and 3</u>

1) Raymond, 1979; 2) Sloan, 1975; 3) Richard Stevens, personal communications; 4) Anderson, 1970; 5) U.S. Public Health Service, unpublished file data; 6) Stan Justin, personal communication; 7) Alaska Department of Environmental Conservation, 1980a; 8) Fred Anderson, personal communication; 9) Dan Egan, personal communication; 10) Tom Miller, personal communication; 11) U.S. Geological Survey, 1978; 12) Turner, et al., 1980; 13) Miller, 1973; 14) Miller, et al., 1973; 15) Alaska Department of Environmental Conservation, 1980b; 16) Lester Erhart, personal communication; 17) Steve Schwab, personal communication; 18) Pat Moore, personal communication; 19) Fred Jordan, personal communication; 20) Brumbaugh, 1977; 21) Anonymous, 1980; 22) U.S. Geological Survey, 1957; 23) Waring, 1917; 24) Don Honea, personal communication; 25) Bill Swan, personal communication; 26) Betsy Hart, personal communication; 27) Albert Kangas, personal communication; 28) Webb, 1979; 29) U.S. Geological Survey, 1968; 30) Fred Stickman, Jr., personal communication; 31) Leon Madros, personal communication; 32) Steve Gerlek, personal communication; 33) Henry Deacon, personal communication; 34) Calvin Chase, personal communication; 35) U.S. Fish and Wildlife Service, 1962; 36) Larry LaVine, personal communication; 37) Dick Snyder, personal communication; 38) Bainbridge, 1977b; 39) Leroy Changsak, personal communication; 40) Linford, 1979; 41) Dave Cooper, personal communication; 42) Bainbridge, 1977a; 43) Bainbridge, 1977e; 44) Bainbridge, 1979; 45) Father Louden, personal communication; 46) Bainbridge, 1977d; 47) Young, 1977; 48) Bainbridge, 1977c; 49) Patrick Phillip, personal communication; 50) Stan Jujan, personal communication; (51) Mike Joseph, personal communication; 52) Victor Tumuwak, personal communication; 53) This report.

Appendix Table 2. Water availability, Koyukuk River region, Lower Yukon River Hatchery Site Investigation. Letters in parentheses refer to additional data available in Volume II: C = water quality records; P = partial water quality records; W = well log; D = aquifer draw down log. Entries not referenced attributable to this report.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
47	S. Fork Koyukuk River				Reported year round open water area w/fall chums 12.9 km below confluence of Jim River	3
48	Middle Fork Koyukuk River	2/4/81			Small ±15 m open water section eminating from ravine on south bank 2 bends above Bettles Field.	
49	Alatna Bluff Spring	2/5/81	0		No water flow, 90 cm snow cover at time of visit. Previously reported open water spring.	3
50	Unnamed creek, Allakaket	2/5/81			At east end of village. Color 70 units. Fluoride 0.8 ppm. Frozen solid at time of visit.	4
51	PHS test well #1, Allakaket	8/26/78	57		Drilled 1973. 10.7 m deep. Aquifer connected to river. (C, W, D)	5
52	Allakaket School well	2/4-7/81	30	1.9	11.1 m deep. Aquifer connected to river. (C)	5, 6, 53
53	Koyukuk River at Allakaket				(C)	7
54	Clear Creek near Hogatza				Reported spring fed system with year round open water. Summer chum present.	8, 9
55	Caribou Creek near Hogatza				Reported spring fed, summer chum system with year round open water downstream from Hogatza Rd. crossing.	8, 9
56	Unnamed spring near Hogatza				Reported between Clear and Bear Creeks along Hogatza Rd., unverifiable by USGS.	9, 10
57	Bear Creek near Hogatza	8/8/77	10,200	15.0	At east edge of Hogatza Mine, 1.3 km upstream from mouth. (C)	11
58	Pocahontas Hot Spring near Hughes				No landing strip.	12
59	Hot Springs Creek near Hughes				No landing strip. Springs 9.6 km off Koyukuk River.	12

Appendix Table 2 continued.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
60	Tunalkten Lake Hot Spring near Hughes				Reported low flow, warm spring with no direct discharge to Koyukuk River.	12
61	Hughes PHS well	5/19/73	57		30.5 m deep. (C, W)	5
62-65	(Deleted)					
66	North Fork Huslia River			≧50°	Reported hot springs near headwaters w/chum salmon present in system.	8, 13, 14
67	Billy Hawk River			≧50°	Reported hot springs near headwaters w/chum salmon present in system.	8, 13, 14
68	Huslia PHS well	7/1/73	90		70.1 m deep. (C, W)	5
69-92	Huslia wells				24 residential wells, 15.2 m to 21.3 m deep. (P)	5
93	Koyukuk VSW well	10/3/75	23		57.9 m deep. (C, W)	5, 15

Key to References. See Appendix Table 1.

Appendix Table 3. Water availability, Yukon River region, Lower Yukon River Hatchery Site Investigation. Letters in parentheses refer to additional data available in Volume II: C = water quality records; P = partial water quality records; W = well log; D = aquifer draw down log. Entries not referenced attributable to this report.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
94	Bear Creek near Tanana				Reported to remain open year round w/summer chums. Recommended by Tanana City Council as rehab site.	16, 17
		2/4/81			Aerial overflight. No open water observed.	
95	Hess Creek near Tanana				Reported w/sections remaining open year round.	17, 18, 19
96	Stevens Creek near Tanana				Spring fed open water section reported 24.1 km up creek at Sandusky Creek.	18, 19
97-99	(Deleted)					
100	Texas Creek near Tanana				Reported w/sections remaining open year round w/summer chums	16
101	Morlock Creek near Tanana				Reported w/sections remaining open year round w/summer chums	16
102	Garnet Creek near Tanana				Reported w/sections remaining open year round	18, 19
103	Tanana PHS Hospital well	8/28/76	190		47.2 m deep. Drilled 8/76. (C, W, D)	5, 20
104-109	Tanana private wells				All hard water, low yield. (C)	5
110	Bear Creek near Tanana				Surplus White Alice site, 14.5 km by road, north of Tanana. Annual flow est. fluctuate 17,000 to 214,100 l/min.	17, 18
111	Tanana PHS well	9/29/80	4		59.1 m deep. (C, W)	5, 21
112	NC Creek, Tanana	9/27/80	3,300	0.6	Organic stain. Freezes up in winter.	16
113	Tozitna River				Year round open water site at junction of Tozitna and Ptarmigan Cr. Submerged spring reported 1.2 km downstream of confluence with Crooked Cr. (C)	16, 17, 22

Appendix Table 3 continued.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
114	(Deleted)					
115	Horner Hot Springs	1917		47.0	Located 1.6 km north of Yukon. 7 springs total. (C)	14
		9/29/80	170	48.0	Main spring.	
116	Horner Hot Springs Cr.	9/29/80	12,700	6.0	Temp. and flow at mouth	
		2/18/81	1,100	0.8	Temp. and flow at mouth	
117	Nowitna River	9/28/80			Aerial observation. Heavily silted.	
		2/17/81			Aerial observation. Frozen, no open leads.	
118	Deer Creek near Ruby				Locally known as Deep Creek. Remains open year round.	24
		9/28/80			Aerial observation rust colored.	
		2/17/81			Aerial observation. Frozen, no open leads.	
119	New Ruby School well	3/7/79	13	1.1	Drilled by Swan Drilling. 95.7 m deep. (C, W)	5, 15, 25
120	Ruby PHS well	2/17/81	81	0.5	Located west of store. (C, W, D)	
		7/26/81	78	1.7		
121	Ruby Roadhouse well	9/28/80	4	0.5	19.8 m deep in limestone bedrock crack.	15, 26
122	Albert Euryanna well, Ruby			0.5	Located across street from Ruby Roadhouse. Draws from same bedrock crack. (C)	5, 26
123	Ruby Spring	9/28/80	13	2.6	Bacterial contamination summer 1979. (C)	15, 24
		2/17/81	0	0	Slight ice upwelling 183 m downhill from spring.	
124	Three Mile Seep near Ruby	9/28/80		2.8	MP 2.7 Ruby-Poorman Rd. Collection pond near road. Traditional watering point. Source is 90 m west of road. Small seepage only. No natural coliform count. (C)	15, 24, 53

Appendix Table 3 continued.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
124	(cont.)	2/17/81	0		70 m long glacier near road. No visible flow.	
		7/26/81	2.4	5.0	Discharge from collection pond through wood pipe near road. Source flowed 4.3 lpm @1.8°C.	
125	Boston Creek near Ruby				MP 10 Ruby-Poorman Rd. Locally called 10 Mile Seep. Traditional watering point at culvert w/"soft" water. Suspected to be spring fed. Low natural coliform count. Glaciates in winter.	15, 24
		7/26/81	990	3.0		
125a	Unnamed spring near Ruby	7/26/81	28	9.2	MP 13.8 Ruby-Poorman Rd. Tributary of New York Cr. Spring source 6 m east of road.	
125b	Long Creek	7/26/81	3,300	5.9	MP 20.8 Ruby-Poorman Rd. At road crossing. Possibly spring fed. Clear water, gravel bottom.	
126	Unnamed spring near Long	Spring 1980			MP 33.5-34.1 Ruby-Poorman Rd. Observed flowing "heavily" on hillside. No flow reported in winter.	24
		7/27/81	2,300	5.0	1 km long seepage area on east side of road. 5 areas in which water was channelized had flows betweem 29 amd 140 lpm.	27
127	Crooked Creek near Long				(C)	22
128	Midnight Creek Spring near Long				MP 35.5 Ruby-Poorman Rd. Reported year round spring at head of creek.	27
		7/27/81	11,000	2.1	At culvert. Highest clear water spring ~600 m east and 20 m above culvert. 710 lpm @1.2°C. 13 spring vents located 5 m downstream from highest spring. Total flow 60 lpm @3.5°C with apparently high iron concentration. Visibility ~5 cm. Numerous small clear water spring seeps along creek bank from highest spring to road crossing.	
129	Little Melozitna Hot Spring		230	28 - 38	Spring located on west bank. H_2S present.	12

Appendix Table 3 continued.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
130	Melozi Hot Springs		492	55 - 56	Unimproved airstrip adjacent. (C)	8, 14, 23, 28
131	Melozi Hot Springs Creek				Very good chum system. Some kings present. Adjacent to hot springs w/airstrip. (P)	8, 28
132	Grayling Creek near Ruby				Reported to remain open year round.	24
133	Melozitna River				Reported to remain open year round in several sections between 400 m and 500 m upstream. (C)	15, 29
		2/18/81			Ground survey lower 3.2 km. Air temp -40°C. No open water observed.	
134	Yuki River near Galena	10/1/80			Aerial overview - turbid. Subject to winter ice overflow.	
135	Kelly Creek near Galena				Reported fall chum system w/possible spring seep.	8
136	Kala Creek near Galena	10/1/80			Aerial overview - heavy rust stain. King and chum salmon system.	
137	Galena Creek near Galena	10/1/80			Aerial overview - extremely turbid.	
138	Kincaid Creek near Galena	10/1/80			Aerial overview - extremely turbid.	
139	Bishop Creek near Galena	10/1/80			Aerial overview - extremely turbid.	
140	Pilot Mtn. Slough near Galena	10/1/80			Aerial overview - turbid, same color as Yukon.	
141	Galena VSW well	4/10/79	95	2.2	Alexander Lake site. 44.8 m deep. Raw water reddish in color. (C, W)	5
142	Galena AFB well				(C)	5
143	Galena new housing well	4/9/72	98		40.2 m deep. (W)	5
144	Mukluk Creek, Nulato	10/1/80	45,500	2.0	Organic stain. Visibility 61 cm.	

Appendix Table 3 continued.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
145	American Creek near Nulato				Tributary of Kaiyuh River. Reported not to freeze.	30
146	Nulato River	10/1/80	1,141,900	3.2	King and chum system. Reported to remain ice free at junction of N. and S. forks.	30, 53
147	Nulato VSW well		38		(C)	5, 15
148	Nulato Subdivision well		38		91.4 m m deep. Hard and alkaline. (C, W)	5, 15
149	Unnamed slough near Kaltag				Across Yukon from Kaltag. Reported to remain open year round.	31
150	Unnamed spring near Kaltag				Submerged spring at fork of Kaltag River 2.4 km above mouth (c)	5, 32
151	Unnamed spring near Kaltag	12/19/76	157 - 378	1.1	At base of hill on south fork Kaltag River 1.6 km above fork. Flow estimated visually.	32
152	Kaltag River	9/30/80	428,200	4.0	Recorded at 400 m upstream. (C)	
153	Kaltag PHS well	12/79	28		21.0 m deep. Slight H_2S odor. (C, W, D)	5
154	Grayling Creek	10/17/80	509,800	0.4	Used by PHS for infiltration gallery. Fe 0.56 ppm, TDS 140 ppm, hardness 145 ppm.	5, 53
155	Grayling BIA School well	3/19/66	110	1.1	9.0 m deep. Located in old streambed, periodically went dry in winter.	5, 33
156	Grayling wells				Thirteen wells drilled. No longer in use. (C, W)	5
157	Anvik River	10/16/80	70.8 - 118.8 million	0.5	Side slough, 2.54 cm ice. Main channel reported to have 1.2 m of water under ice in winter. Est. flow.	34, 53
158	Anvik PHS well	10/16/80	110	1.8	29.8 m deep. Slight rust brown color. Slight H_2S odor. (C, W, D)	5, 53
159	Anvik School well	10/16/80			23.5 m deep. Reddish-orange upon standing. Moderate H_2S odor. (C)	5, 53
160	Ted Kreuger well, Anvik				21.3 m deep. (C)	5

Appendix Table 3 continued.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
161	Joe Jerue well, Anvik				14.0 m deep. H_2S odor. (C)	5
162	Calvin Chase well, Anvik	10/16/80	4	3.3	17.4 m deep. Rust colored upon standing. H_2S odor. (C)	5, 34, 53
163	Calvin Chase new well, Anvik	10/16/80	23	3.6	18.3 m deep. Brown upon standing. Slight H_2S odor.	34, 53
164	William Chase well, Anvik		11		18.3 m deep.	34
165	Fish Plant well, Anvik				Drilled summer 1980.	34
166	Unnamed stream near Paradise				Shallow spring-fed lake w/1.6 km stream emptying into Yukon. No spawning habitat.	35
167	Unnamed spring in Holy Cross	10/16/80	430	2.2	Located 1.6 km south of town on road around base of hill.	36, 37, 53
		3/11/81	250	1.6	(C)	
		4/8/81	71	1.6	pH 6.39.	
168	Spring seep in Holy Cross	4/8/81		0	Small seep on road above town. 3.8 cm ice, 2.54 cm water.	
169	Old Holy Cross PHS well	5/15/68	23	3.3	23.5 m deep. Water present in sand rock crack. Subject to winter dry up. (C, W)	5, 53
170	New Holy Cross PHS well	10/16/80	83	2.9	36.6 m deep. (C, W)	5, 53
		4/8/81	95	2.4	pH 6.5.	
171	Shageluk PHS well	9/28/75	110		41.5 m deep. (C, W)	38
172	Unnamed creek near Dogfish Village	4/8/81			Tributary to Tuckers Slough near Mt. Ewaklalik. Aerial overflight. Creek 90% open along observed lower 10 km. Est. 3 m wide, 30 cm deep, w/current ripples.	

Appendix Table 3 continued.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
173	Unnamed creek near Paimiut	4/8/81			Aerial observation. Open water in small creek originating in hillside ~300 m upriver from junction of Tuckers Slough with Yukon River.	
174	Dogfish Village Creek	4/8/81			Aerial observation. Substantial icing along creek course through town, no open water observed.	
175	Unnamed spring near Russian Mission				Reported on creek 2.4 km downriver on Yukon east bank. Reported warm to touch, 60-90 cm across. Summer chums reported.	39
176	Russian Mission PHS well	10/15/80	227	6.1	35.7 m deep. (C, W, D)	40, 53
		4/8/81	110	3.6		
177	Russian Mission old PHS well	6/2/68	95	3.3	39.0 m deep. Water in sandstone crack. (C, W, D)	5, 40
178	Nunvotchuk Lake near Russian Mission	4/8/81			Aerial observation. Small open water at outlet of chum salmon streams at head of lake.	
179	Engineer Lake near Marshall				Located 24.1 km upriver on NE bank from Marshall. 8 km long, good chum salmon system. Lake accessible from Yukon by skiff.	41
		4/8/81			Aerial overflight. No open water observed.	
180	Unnamed stream, Engineer Lake	4/8/81			Aerial overflight. Stream headwaters in Bend Mtn. Open water in lower 6.4 km.	
181	Willow Creek Soda Springs near Marshall	8/25/16	5	10.0	8 km up Willow Creek on road from Willow Creek landing. 7 springs reported, 3 still active @5.4 lpm ea.	23, 41
		4/8/81			Aerial overflight. Unable to locate springs.	
182	Spruce Creek near Marshall	4/8/81			Aerial overflight. Creek 80% open. Est. 3.0 m wide. Reported chum system.	35
183	Joe Wise Creek near Marshall	4/8/81			Aerial overflight. Creek 80% open. Est. 2.1 m wide.	

Appendix Table 3 continued.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
184	Wilson Creek near Marshall	8/5/57	51,000	9.4	Reported to flow year round w/some open leads. Summer chums.	35, 41
		4/8/81			Aerial overflight. Open leads in lower 2.0 km.	
185	Marshall Airport Spring	10/16/80	190	1.8	91.4 m from airport. 15.2 m south of road. 12.2 m head above old cabin site on Wilson Slough.	
		3/11/81	28	1.2	(C)	
		4/8/81	14	1.1	pH 7.20.	
186	Old Marshall PHS well	8/3/75	95		26.5 m deep. Water table drops below intake (22.5 m) in winter. (C, W)	5, 42
187	New Marshall PHS well	10/16/80	16	1.2	54.9 m deep. (C)	42, 53
188	Marshall REAA School well				Two wells 25.9 m deep. No longer in use. (C)	41, 42
189	Pilot Station PHS well	1/1/77	95		91.4 m deep. (C, W)	43
190	Pilot Station HS well	11/7/78	110		35.0 m deep. Developed in fractured rock. (C, W, D)	44
191	Pitkas Point well				24.4 m deep. (C)	5
192	St. Marys Mission Spring	11/10/80	23	3.3	Located within Mission complex in front of dorms.	
		3/11/81			Slight icing. No water flow observed.	
		4/8/81	0		Water seepage apparent. No measurable flow.	
193	St. Marys Mission well	4/8/81			Est. 36.6 m deep. In hillside behind spring. Reported to produce 22,700 to 30,300 lpm.	45
194	Alstrom Slough, St. Marys	11/10/80	14,200	0	Used by PHS for infiltration gallery. Suspected spring fed system. (C)	5, 53
		4/8/81		0	15.2 m below culvert. 46 cm ice. 6.35 cm water w/current ripples. pH approx. 5.0 to 5.6.	

Appendix Table 3 continued.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
195	Andreafsky River				King and chum system. (C)	22
196	AVEC well #1, St. Marys	6/72	110		61.0 m deep. Not used. (W)	5, 46
197	City dock well #2, St. Marys	12/72	190		17.4 m deep. Not used. (W)	5, 46
198	Andreafsky townsite well #3, St. Marys	12/72	95		8.5 m deep. Not used. (W)	5, 46
199	Sheppards Trading Post well #4, St. Marys				16.8 m deep. Not used. (W)	5, 46
200	City dock well #5, St. Marys	6/74	57		25.3 m deep. Not used. (C, W)	5, 46
201	Sewage Lagoon well #6, St. Marys	9/74	57		36.6 m deep. Not used. (W)	46
202	Pumphouse well #7, St. Marys	12/74	19		61.6 m deep. Not used. (W)	46
203	SOS High School well #8, St. Marys	9/75	210		64.0 m deep. Not used	46
204	Well #9, St. Marys	7/76	140		Located near Alstrom Creek. 16.5 m deep. Infiltration gallery site. (C, W, D)	46
		4/8/81		0.6	pH 6.73. Reported 130 lpm.	
205	Unnamed spring, Mt. Village	11/11/80	28	1.5	200 m west of town along Yukon.	
		3/11/81		0	Heavily glaciated. 150 cm deep by 60 cm wide hole open in overflow. Flow under ice unknown.	
		4/8/81		0.2	Heavily glaciated 76 to 91 cm standing water under ice lens. Flow unknown.	
206	Unnamed spring, Mt. Village	4/8/81			Located in ravine adjacent to Lower Yukon/Kuskokwim Aquaculture Assoc. Hatchery. Icing present. No free water observed. (C)	

Appendix Table 3 continued.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
207	Archuelinguk River #1 near Mt. Village	4/24/77		0.5	9.6 km upriver. Water depth 119.4 cm. Ice depth 88.9 cm.	47
208	Archuelinguk River #2 near Mt. Village	4/24/77	28,900	0.5	12.8 km upriver. Water depth 55.9 cm. D.O. 7 mg/liter. Slight sulferous odor. Open water.	47
209	West Fork Archuelinguk R. near Mt. Village.	4/24/77			Frozen to bottom.	47
210	Mt. Village PHS well #1	6/75	110		68.6 m deep. Static level varies 0-9.1 m. Not used. (D, W)	48
211	Mt. Village PHS well #2	11/11/80	83	1.7	42.7 m deep. (C, D, W)	48, 53
212	Mt. Village High School well	6/75	87	2.2	59.4 m deep. Not used. Temp. taken 3-14-79 at wellhead by ADEC. (C, W, D)	15, 48
213	Mt. Village PHS test hole #1	4/71	15		31.4 m deep. Not used. (C, W)	48
214	Mt. Village PHS test hole #2	5/71	38		18.3 m deep. Not used. (C, W)	48
215	Mt. Village PHS test hole #3	5/71	57		13.9 m deep. Not used. (C, W)	48
216	Mt. Village PHS test hole #4	4/73	84		25.9 m deep. Not used. (W)	48
217	Mt. Village PHS test hole #5	4/73	19		11.6 m deep. Not used. (W)	48
218	Alakanuk VSW facility				Surface water from Yukon treated by facility. (C)	15
219	Alakanuk BIA wells				BIA drilled two wells, 29 m and 36.6 m deep--saltwater. PHS drilled 31.1 m well for BIA--saltwater.	49
220	Black River near Alakanuk				North side tributaries to Black R. are reported clear water salmon systems. Boat/helicopter access.	49

Appendix Table 3 continued.

Site #	Name	Date	Flow (liters/min)	Temp. (°C)	Comments	Reference
221	Pastolik R. near Kotlik				Suspected spring fed clear water system. Winter flow unverified.	50, 51, 52

Key to References. See Appendix Table 1.

Appendix Table 4. Preliminary Alaska Department of Fish and Game water quality standards for salmon aquaculture, 1977.

Alkalinity	at least 20 mg/l as $CaCO_3$
Aluminum	<0.01 mg/l
Ammonia (unionized)	<0.02 mg/l
Arsenic	<0.05 mg/l
Barium	<5.0 mg/l
Cadmium	<0.0005 mg/l (≦100 mg/l alkalinity) <0.005 (≧100 mg/l alkalinity)
Carbon Dioxide	<1.0 mg/l
Chloride	<4.0 mg/l
Chlorine	<0.003 mg/l
Chromium	<0.03 mg/l (fish and other aquatic life)
Copper	<0.006 mg/l (≦100 mg/l alkalinity) <0.03 mg/l (≦100 mg/l alkalinity)
Dissolved Oxygen	>8.0 mg/l
Fluorine	<0.5 mg/l
Hydrogen Sulfide	<0.003 mg/l
Iron	<0.1 mg/l
Iron Bacteria	(includes <u>Sphaerotilus</u> sp.) - prefer water with a lack of enough nutrients to inhibit growth.
Lead	<0.02 mg/l
Magnesium	<15 mg/l
Manganese	<0.01 mg/l
Mercury	<0.0002 mg/l
Nickel	<0.01 mg/l
Nitrate (NO_3)	<1.0 mg/l (<0.10 mg N/l)
Nitrite (NO_2)	<0.1 mg/l (<0.01 mg N/l)
Nitrogen (N_2)	<110% total gas pressure (<103% nitrogen gas)
Petroleum or derivatives	None
pH	6.5 - 8.0
Potassium	<5.0 mg/l
Radiation count (background)	Information only
Salinity	<5.0 ppt
Selenium	<0.01 mg/l
Silver	<0.003 mg/l (fresh water) <0.0003 mg/l (salt water)
Sodium	<75.0 mg/l
Sulfate (SO_4^{-2})	<50.0 mg/l
Temperature	0° - 15°C
Total Dissolved Solids	<400.0 mg/l
Total Settleable Solids	<80.0 mg/l (25 JTU)
Uranium	<0.1 mg/l
Vanadium	<0.1 mg/l
Zinc	<0.005 mg/l
Zirconium	<0.1 mg/l

Note: Synergistic and antagonistic chemical reactions must be considered when evaluating a water source against these criteria.

Appendix Table 5. Access and gravel availability for sites in the Lower Yukon River region having the most potential for hatchery development. Abbreviations: Exc = excellent; sum = summer only; unk = unknown; lim = limited.

Name (site #)	Gravel Avail.	Airport (m)	Access Road	Access Barge	Access Boat
Dietrich River (1)	Good	1,372	Exc	No	No
Spring near Dietrich River (4)	Good	1,585	Exc	No	No
Jim River at Prospect Camp (23)	Good	1,524	Exc	No	No
Clear and Caribou Cks (54, 55)	Good	975	Sum	Yes	No
Horner Hot Springs (115)	Unk	None	None	Yes	Yes
Ruby PHS well (120)	Good	793	Good	Yes	No
Midnight Creek Spring (128)	Good	Unk	Sum	Yes	No
Melozi Hot Spring (130)	Unk	366	None	No	Yes
Holy Cross Spring (167)	Lim	1,036	Poor	Yes	No
Holy Cross PHS well (170)	Lim	1,036	Good	Yes	No
Unnamed Creek near Dogfish Village (172)	Unk	None	None	Yes	Yes
Russian Mission PHS well (176)	Lim	457	Good	Yes	No
Marshall Airport Spring (185)	Fair	427	Good	Yes	No
St. Mary's (193, 194)	Good	1,829	Good	Yes	No